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MULTICYLINDER DIESEL ENGINE TESTS WITH UNSTABILIZED WATER-IN-FUEL EMULSIONS

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U.S. DEPARTMENT OF TRANSPORTATION

RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
TRANSPORTATION SYSTEMS CENTER • CAMBRIDGE MA 02142

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CG-D-27-80

MULTICYLINDER DIESEL ENGINE TESTS WITH UNSTABILIZED

REPRINT JUNE 1981

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16. Abstract

Two diesel engines representative of the four-stroke cycle and two-stroke cycle main propulsion units installed in U.S. Coast Guard WPB class cutters were operated in a test environment in an attempt to demonstrate significant fuel savings associated with water-in-fuel emulsions. The engines were connected to a dynamometer in a laboratory test cell. A prototype fuel system was assembled that would supply unstabilized emulsions for which the water concentration could range from zero to 25 percent of the total volume of liquid supplied to the engine as fuel. An analysis of boat operation was performed in order to identify the most frequently used engine settings, and both engines were operated at test points representative of boat prop load performance.

The test results for the four-stroke cycle engine indicated that an average diesel fuel saving of about 2.5 percent could be obtained at the most frequently encountered operating conditions using water concentrations of 15-25 percent. Statistical analysis procedures suggest a 90 percent confidence in the measured results. Significant reductions in exhaust smoke were also observed, although the exhaust stream opacity was low throughout the tests. For the two-stroke cycle engine, no statistically significant reduction in fuel consumption could be identified.

Measurements of gaseous exhaust emissions were obtained for both engines; in general, the emissions increased with the presence of water in the fuel. Measurements of particulate emissions for the two-stroke cycle engine suggested only a slight effect of water concentration. No adverse effect on engine hardware could be associated with the presence of water in the engine fuel system.

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PREFACE

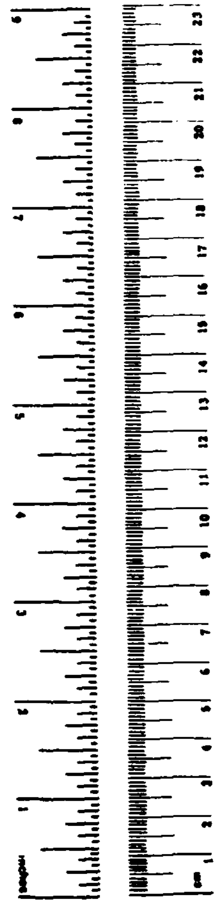
This work was performed for the U.S. Department of Transportation, U.S. Coast Guard, Office of Research and Development, under a contract issued by the Transportation Systems Center. The Technical Monitors were Fred Weidner (USCG) and Robert Walter (TSC). The laboratory tests were performed by Rodney Bauer of the Department of Engine and Vehicle Research, Southwest Research Institute.

Engines were made available to the program by the Cummins Engine Company, Inc., and by the Detroit Diesel Allison Division of General Motors Corporation. The cooperation of these organizations is sincerely appreciated.

METRIC CONVERSION FACTORS

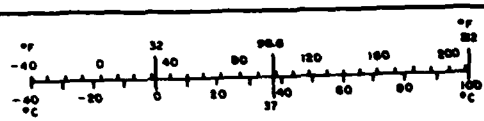
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

The current emphasis on fuel conservation has prompted the study of many devices and techniques oriented toward a reduction in engine fuel consumption. This report describes the procedures used and the results obtained during a study of unstabilized water-in-fuel emulsions as fuels for engines representative of U.S. Coast Guard main propulsion systems.

The complete program involved an investigation of two high-speed diesel engines with nominal maximum power ratings in the 1000 hp range. A Cummins VTA-1710 engine was used to represent the military version (VT12-900M) that is utilized by the USCG. In addition, a Detroit Diesel 12V-149TI engine was employed for the acquisition of data representative of the 16 cylinder version installed in the USCG cutters.

1.1 BACKGROUND

The use of water-in-fuel emulsions for fuel conservation has been a subject of continuing interest for several years. During 1977, Southwest Research Institute conducted a program for the Department of Transportation in which fuel-water emulsions were examined in the context of a single-cylinder test engine. The results obtained during that study indicated that a reduction in fuel consumption on the order of five percent might be available for engines representative of marine propulsion.[1] It was recommended that the testing effort be continued using multi-cylinder engines, and the present study describes the partial fulfillment of that recommendation.

Various investigators have recommended the use of different devices and philosophies for the production of water-in-fuel emulsions used as engine fuels. One approach suggests the addition of surfactant compounds to the fuel-water mixture. The surfactants stabilize the emulsions and allow batch mixing of fuel supplies. For the present study, however, this approach was not considered feasible, since the USCG would prefer to avoid the requirement for precise blending of fuel additives with the large quantities of fuel utilized for patrol boats. Furthermore, it was considered necessary to view the emulsified fuel as an option to clear diesel fuel, and the storage of a second bulk fuel aboard existing cutters was not considered appropriate.

This study deals with the use of unstabilized emulsions as engine fuels. The water and fuel were emulsified immediately prior to use by the engine, and emulsified fuel that was supplied to the engine but not burned was recycled through the emulsifier circuit.

1.2 OBJECTIVES

The initial goal of the study was the identification and the specification of an appropriate emulsification device. It had previously been observed that some devices offered for use as fuel emulsification systems were inappropriate to shipboard operation by virtue of physical size or power requirements. Furthermore, it was not clear that all devices were equally capable of providing useful emulsions. Therefore, the initial program phase was devoted to selection of an emulsification device.

Following the specification and purchase of a suitable emulsifier, the program objective was the determination of the effect of the emulsified fuels on engine operation. All tests were performed in a laboratory environment; the engines were connected to a dynamometer. Particular emphasis was placed upon fuel conservation, but measurements of exhaust emissions were also obtained. A further objective was the determination of results on a statistically significant basis in order that a numerical confidence could be placed in the results.

As an additional program objective, it was specified that encouraging results from the test bed studies would yield design information appropriate to the assembly of a prototype fuel emulsification system for shipboard use. The final program phase would involve field testing of the prototype on a USCG cutter.

1.3 APPROACH

The program was initiated with a selection process devoted to the definition of emulsification systems appropriate to the study. Invitations were sent to all individuals or companies known to be involved in the development of emulsification systems, and an advertisement was placed in the Commerce Business Daily that outlined the program requirements. Six prospective suppliers responded to the invitation and offered devices for evaluation in the SwRI laboratory.

A system was provided by SwRI that would supply metered quantities of fuel and water to the prototype systems on a uniform basis. The emulsification systems were exercised within their performance limits as defined by the supplier, and samples of water-in-fuel emulsion were obtained over the 0 to 25 percent concentration range that was of interest. Immediately following collection of each sample, the time required for accumulation of an obvious separation layer was observed. This process allowed the assessment of the capability of each device to produce an emulsion that would be useful during the engine studies.

In addition, each prospective emulsification device was evaluated on the basis of energy usage, physical size, complexity, compatibility with the shipboard environment, and the need for auxiliary hardware such as pumps and controllers. Individual evaluations were performed by representatives of SwRI, the Transportation Systems Center, and the USCG. As a result of the evaluation process, two emulsification systems were selected for use during the engine operation phase of the program, and purchase orders for units of an appropriate size were executed.

Since the response of the engine fuel system to the presence of water was unknown, a brief sequence of test runs was performed using stabilized emulsions containing 5 and 20 percent water by volume. The single purpose of these tests was the determination of any observable detrimental effects on engine operation as a result of water in the fuel system. No detrimental effects were observed, therefore the testing with unstabilized mixtures was initiated.

During all of the test sequences the laboratory engine was operated at controlled speeds and loads representative of the cutter prop load at each speed. On this basis, the maximum engine output would be observed only at the engine rated speed. Although some test runs were performed at maximum speed and load, the data were of interest only for certification of the fact that the engine met the ratings specified by the manufacturer. At the other test speeds the prop loads were considerably below the maximum possible engine output.

Throughout the bulk of the test program, the engine remained in the configuration appropriate to the use of diesel fuel alone. Since the fuel-water emulsion was regarded as an alternate fuel for boat operation, it was not considered appropriate to optimize the engine operating parameters for emulsified fuel use. It is possible that fuel consumption results different from those obtained could have been achieved by adjusting the engine operating parameters; the injection timing is particularly significant in this context, and some tests were performed with timing variation on the two-stroke cycle engine.

The emulsifier purchased for use during the tests was integrated into a fuel system capable of supplying the engine demand at any speed and load. The fuel system included ample provision for maintaining the state of the emulsions and for re-emulsifying fuel returned from the engine. In addition, a provision was included to allow sampling and subsequent observation of quantities of emulsified fuel immediately prior to introduction into the engine. Observation of these samples allowed additional verification of the water concentration of the emulsion.

During the test runs the engine was operated at selected points on the prop load curve with various water concentrations. Each test sequence, which occupied one day, involved operation of the engine at a single speed-load point. The first test run was performed with clear diesel fuel, followed by tests at 5, 10, 15, 20, and 25 percent water. Upon completion of these runs the fuel system was flushed and the test with clear diesel fuel was repeated. During the performance of each test run, extensive observations of fuel consumption and other engine operating parameters were made.

The complete body of data includes information at speeds along the entire prop load curve for each test engine. In addition, the data include extensive testing at two speed-load points for the Cummins engine; the two points represent high utilization by operating USCG cutters. The data allow the determination of the optimum water concentration at each speed-load point; this information would be useful for the design of a shipboard control system.

2. EXPERIMENTAL APPARATUS AND TECHNIQUES

The performance of the experiments associated with this study involved specific equipment, test procedures, and data evaluation routines. The salient features of these items are described in this section.

2.1 EQUIPMENT

The equipment utilized for the evaluation of water-in-fuel emulsions consisted of engines installed in a laboratory test cell, a fuel system uniquely appropriate for the production and distribution of emulsified fuel, and a broad variety of instrumentation used for the acquisition of data. Each of these categories is worthy of an expanded description.

2.1.1 Engines

The engines used aboard USCG cutters of the 82-ft WPB class are manufactured by the Cummins Engine Company and characterized by Model No. VT12-900M. The units have a total displacement of 1710 cubic inches and are rated at 800 shaft horsepower at 2300 rpm. This rating corresponds to approximately 875 brake horsepower at the same speed.

The engine available to this effort was a Cummins Model VTA-1710-C800, the industrial version of the USCG engine described above. The engine is ordinarily rated at 800 brake horsepower at 2100 rpm. The engine was equipped with an automotive type AFC fuel pump rather than the older style marine pump. For the purposes of this study, the fuel pump and governor were modified to allow engine operation up to 2300 rpm, and a maximum power capability of 845 horsepower at 2300 rpm was demonstrated in the laboratory. This value is within the five percent tolerance specified by the manufacturer.

The military and industrial versions of the 1710 engine differ slightly in the timing at which the fuel injection event begins. This difference amounts to approximately three crank angle degrees, and this deviation was not deemed sufficient to warrant the major effort involved in a timing change.

The engines used to power 95-ft WPB cutters are manufactured by the Detroit Diesel Allison Division of the General Motors Corporation; the specific model designation is 16V-149TI. The displacement of each unit is 2384 cubic inches, and each engine is rated at 1235 shaft horsepower at 1800 rpm.

The engine that was available for use during this study was a Detroit Diesel Model 12V-149TI; this unit is a twelve-cylinder version of the USCG engine. During the testing program, the engine was operated at approximately the same horsepower output per cylinder that the marine version would produce. Thus, although the total output of the twelve-cylinder engine was low, the details of engine operation were quite representative of the sixteen-cylinder counterpart.

The major specifications of the engines used during the test program are outlined in Table 2-1, and data from the manufacturers is shown in Appendix A.

2.1.2 Dynamometer and Test Cell

Each engine was installed in a test cell at the SwRI laboratory and connected to an eddy-current dynamometer capable of absorbing up to 1000 horsepower. The engine installation is shown in Figures 2-1 and 2-2. The dynamometer utilized was an absorbing unit only; no motoring capability was available.

The engine speed was determined through the use of a magnetic pickup and a 60-tooth gear installed in the engine-dynamometer coupling. The speed signal was transmitted to a digital counter used as an output device, and, in addition, the signal was supplied to a dynamometer controller capable of maintaining engine speed within a tolerance of one rpm. The dynamometer beam load was measured through the use of a strain gauge type load-cell connected to an output device at the control console. The load-cell was subjected to a weekly deadweight calibration.

2.1.3 Fuel System

A fuel supply system was assembled that would meter, premix, and emulsify the fuel and water in concentrations that were of interest. Although certain

TABLE 2-1. ENGINE SPECIFICATIONS

Cummins Engine Company, Inc. Model: VTA-1710-C800 (VT12-900M) Type: Four Stroke Cycle Bore and Stroke: 5.5 x 6 No. of Cylinders: 12 Displacement: 1710 Cubic Inches Rated Horsepower: 800 at prop shaft Rated Speed: 2300 RPM
General Motors Corporation Detroit Diesel Allison Division Model: 12V-149TI (16V-149TI) Type: Two Stroke Cycle Bore and Stroke: 5.75 x 5.75 No. of Cylinders: 12 (16) Displacement: 1788 Cubic Inches Rated Horsepower: 900 (1200) Rated Speed: 1800 RPM

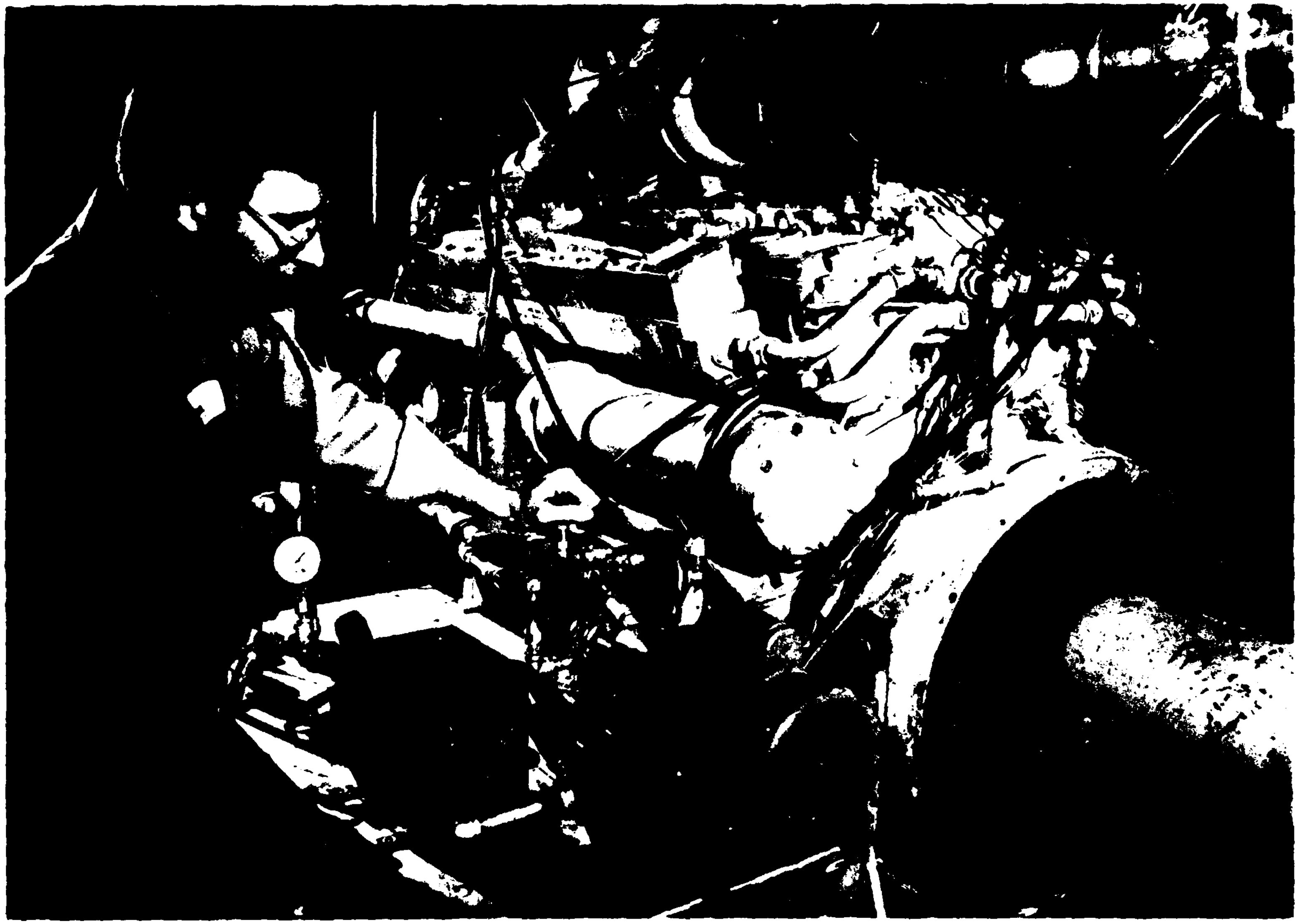


FIGURE 2-1. ENGINE INSTALLATION; CUMMINS ENGINE TESTS

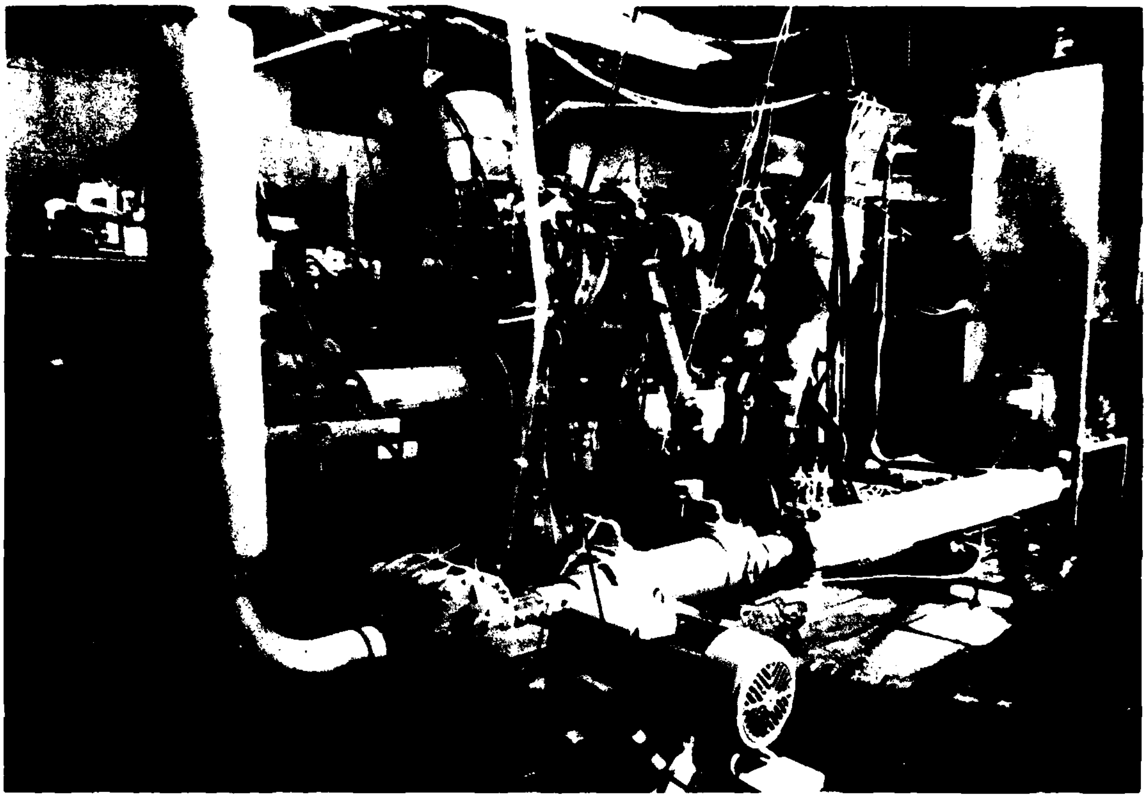


FIGURE 2-2. ENGINE INSTALLATION; DETROIT DIESEL TESTS

features of the system were designed specifically to accommodate the Cummins engine, the same system proved useful for both of the engines tested.

In ordinary operation the fuel would be supplied directly to the injection pump of the engine, and fuel not used by the engine would be returned to a storage tank. The Cummins injection system is unique in that the returned fuel typically contains quantities of gas which must be removed prior to recycling of the unburned fuel through the engine. In usual installations, this capability is provided by a vented storage tank.

For the purposes of this study, it was necessary to assemble a fuel system that would generate the fuel-water emulsion while simultaneously satisfying the requirement for degasification of the return fuel. A schematic diagram of the system used is shown in Figure 2-4, and the fuel system is visible in Figure 2-1. Fuel and water were supplied independently to a mixing tee; this device provided a crude mixture prior to emulsification. Tap water was utilized throughout, and the line pressure provided the driving force. Fuel was pumped from a storage tank into the mixing arrangement. A constant fuel level was maintained in a float-controlled tank having a volume of approximately one-half gallon. This open tank allowed gases trapped in the return fuel to escape prior to fuel recycling. Fuel was removed from the float-controlled tank by a one horsepower gear pump which supplied a pressure of approximately 100 psi to the fuel-water emulsifier. The emulsifier used in this system was a Hydroshear device supplied by Gaulin Corporation; the unit operates by subjecting the fuel-water mixture to an extremely high shear state. A drawing of a typical Hydroshear after Lawson[11] is shown in Figure 2-3. The pressure at the outlet of the emulsifier was typically 20 to 25 psi.

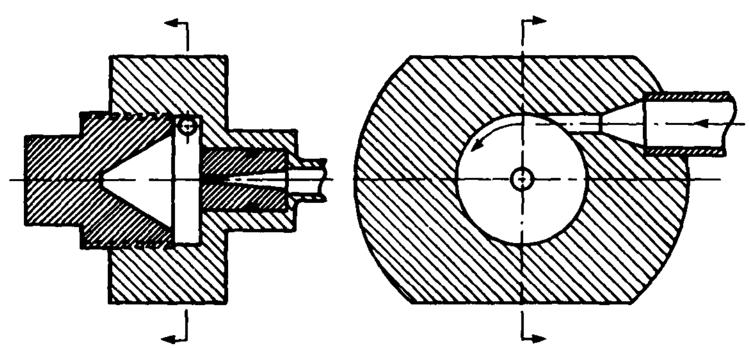


FIGURE 2-3. TYPICAL HYDROSHEAR

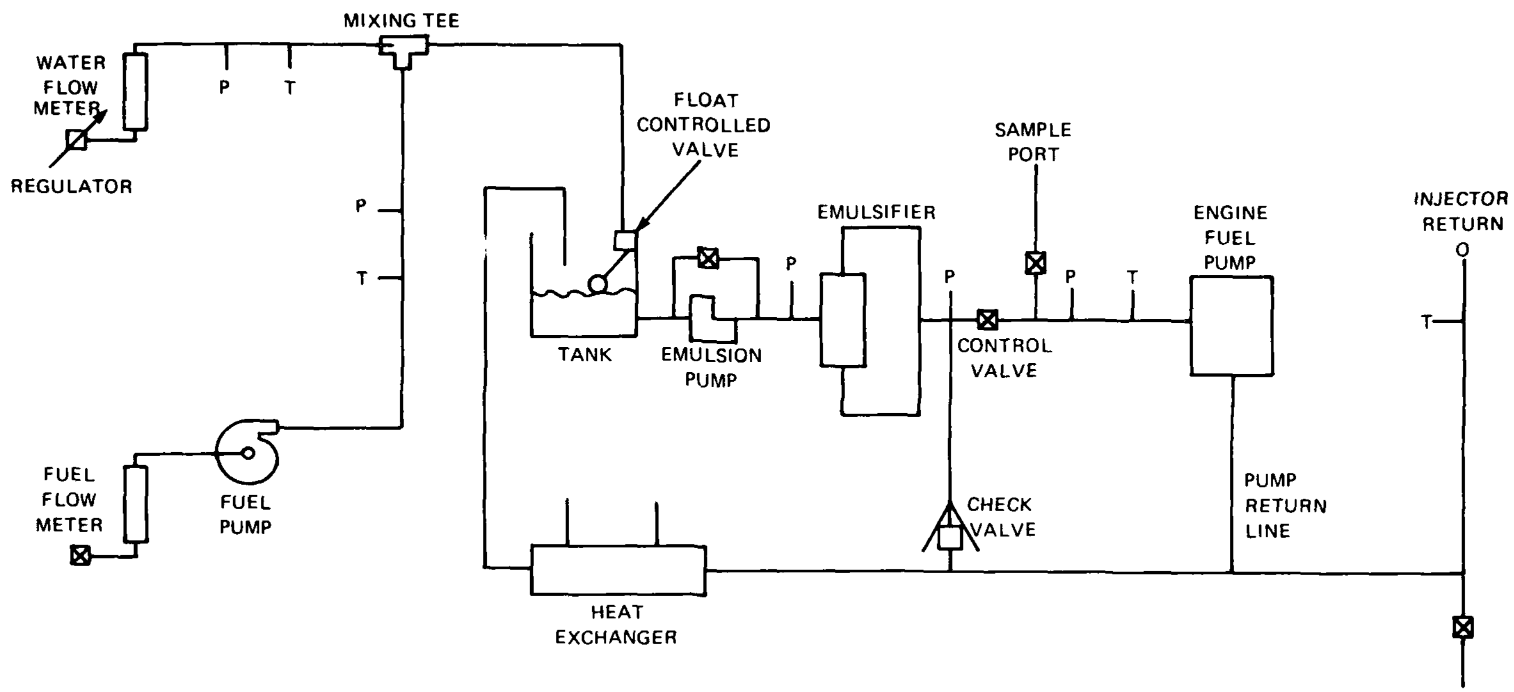


FIGURE 2-4. PROTOTYPE EMULSIFIED FUEL SYSTEM

At the emulsifier outlet, the fuel was directed either to the engine fuel pump or to a by-pass loop. Fuel directed toward the engine passed through a control valve which lowered the pressure to a value below 5 psi in order to meet the requirements of the engine fuel system. Fuel returned from either the engine fuel pump or the engine fuel injectors was routed into the by-pass portion of the system. The unused emulsion was conducted through a heat exchanger for cooling prior to return to the float-controlled tank. Pressures and temperatures were measured at points of interest throughout the fuel supply system, and a sample port was provided at the engine fuel pump for use in the verification of water concentrations.

During the tests, the fuel system was operated at a continuous flow rate approximately equal to the engine maximum demand. Thus, a substantial flow rate was always present in the by-pass loop, and the emulsifier was not subjected to varying conditions as the engine load changed. During steady-state operation, the flow rate of the fuel-water mixture to the float-controlled tank was equal to the rate at which the fuel was consumed by the engine, but the flow through the emulsifier loop was constant.

2.1.4 Instrumentation

The documentation of engine performance using emulsified fuels required the measurement of a number of quantities during engine operation. The individual parameters for which data were recorded during each test run are listed in Table 2-2.

The dry bulb and wet bulb temperatures used for calculation of humidity were measured using mercury-in-glass thermometers. Exhaust temperatures were measured with type K thermocouples, and other temperatures were measured using type J thermocouples. All of the thermocouple readings were obtained through the use of multi-point switches and readout devices appropriate to the thermocouple calibration.

Pressures were measured using Bourdon tube gauges, mercury manometers, or water manometers as appropriate for the value and range of the metered quantity. The value of barometric pressure was obtained during each test run.

TABLE 2-2. DATA OBTAINED FROM TEST CELL

- Speed
- Load
- Fuel Rate
- Pressures:
  - Barometer
  - Oil
  - Fuel Rail
  - Turbocharger Boost
  - Exhaust
  - Turbine Inlet
  - Inlet Depression
  - Fuel Inlet
  - Air Flowmeter
  - Air Filter
  - Emulsifier
  - Fuel Supply
  - Water Supply
- Emissions:
  - Hydrocarbons
  - Carbon Monoxide
  - Nitric Oxide
  - Oxides of Nitrogen
  - Carbon Dioxide
  - Oxygen
  - Smoke
- Water Flow Rate
- Water Concentration
- Temperatures:
  - Engine Coolant
    - Inlet
    - Outlet
  - Oil Sump
  - Fuel Inlet
  - Fuel Mixture
  - Return Fuel
  - Intake Air
  - Cylinder Exhaust
  - Exhaust Manifold
  - Turbine Inlet
  - Compressor Outlet
  - Charge Air
  - Water
  - Cell Air
  - Dry Bulb
  - Wet Bulb
  - Return Fuel Cooler

The flow rate of diesel fuel was continuously monitored through the use of a commercial linear mass flowmeter. However, the primary technique for determination of fuel flow was a direct mass measurement obtained using a platform balance and a stop watch. Using this technique, the time required for consumption of a known mass of fuel was recorded. The mass was adjusted in such a way that typical fuel times were on the order of two minutes, and several readings were obtained during each test run.

The water flow was monitored through the use of a variable area flowmeter installed in the water inlet line. The meter was calibrated prior to the beginning of the test program, and tables were prepared which listed the water flowmeter reading for each desired water concentration over a range of fuel rates applicable to each test point. To establish a particular water concentration in the fuel, the engine operator would read the fuel mass flowmeter, consult the table, and set the water flow rate accordingly. The water concentration was then verified by obtaining a sample of the emulsion at the engine inlet and allowing separation of the water and diesel fuel to occur.

The air flow to the engine was measured using a laminar flow element rated at 2000 cfm. The pressure drops across the flowmeter filter and across the metering element were measured using inclined water manometers, and the air flow rate was established from the meter calibration using corrections for ambient temperature and pressure.

During tests of the Detroit Diesel engine, additional air flowmetering capability was required. The 2000 cfm laminar flow element was used in the air supply to one-half of the engine (one bank of six cylinders). The air flow to the remaining engine cylinders was metered with an ASME flow nozzle installed in an inlet plenum chamber.

Instruments appropriate to diesel engine testing were used for the measurement of gaseous emissions. The concentration of unburned hydrocarbons in the exhaust stream was monitored using a heated flame ionization detector. Nondispersive infrared analyzers were used for measurement of carbon monoxide and carbon dioxide, and a chemiluminescent analyzer was used to establish levels of nitric oxide and oxides of nitrogen. The oxygen level in the exhaust was monitored using a polarographic analyzer. Schematic diagrams of the components of the emissions instrumentation system are shown in Figures 2-5, 2-6, and 2-7, and descriptions of the individual hardware items are provided in Tables 2-3, 2-4, 2-5, and 2-6. Photographs of the instrument console are provided as Figures 2-8 and 2-9.

The exhaust smoke was measured through the use of a USPHS type opacity meter incorporated in the exhaust system at the boundary of the test cell.

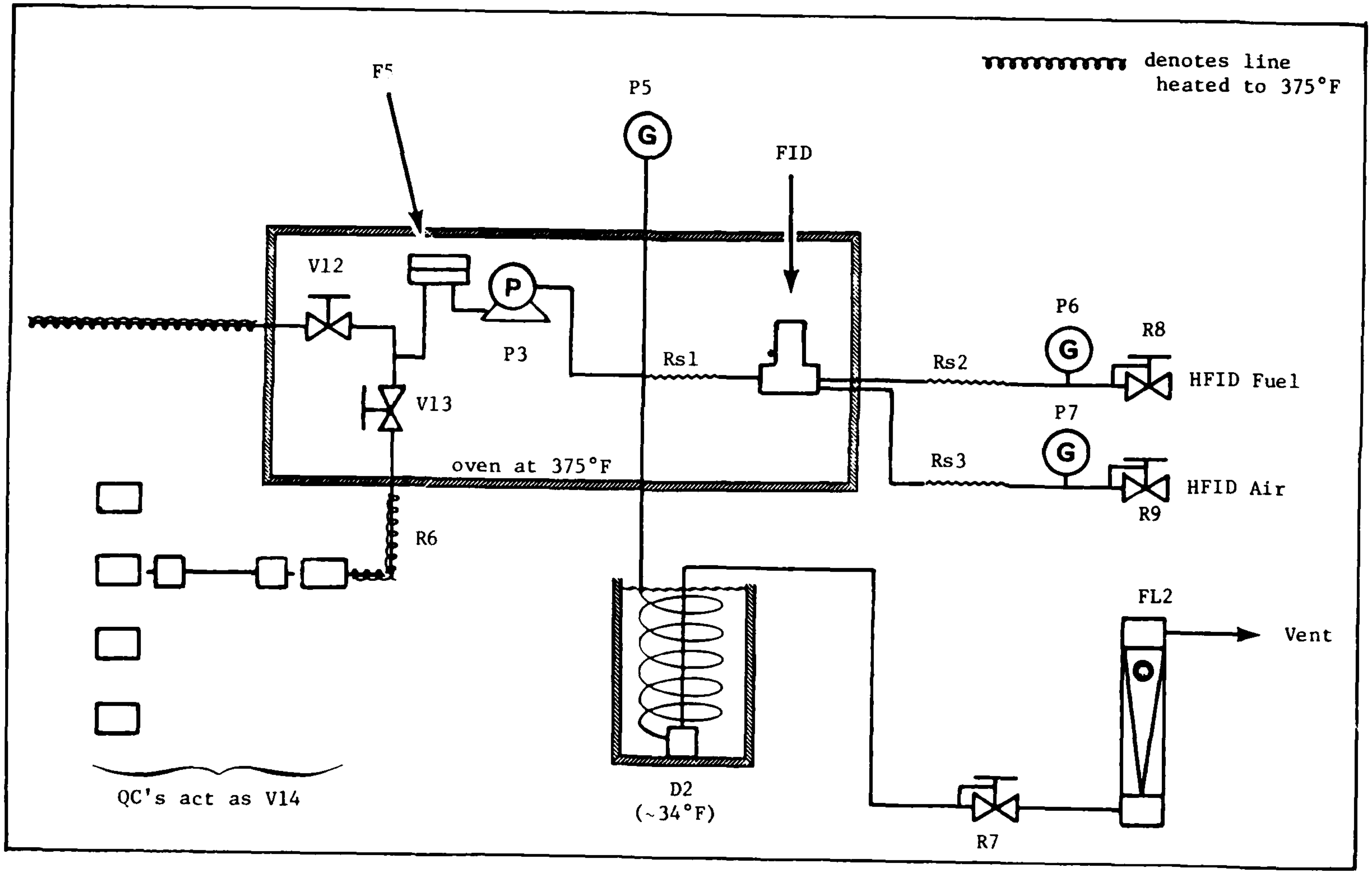


FIGURE 2-5. HYDROCARBON ANALYZER

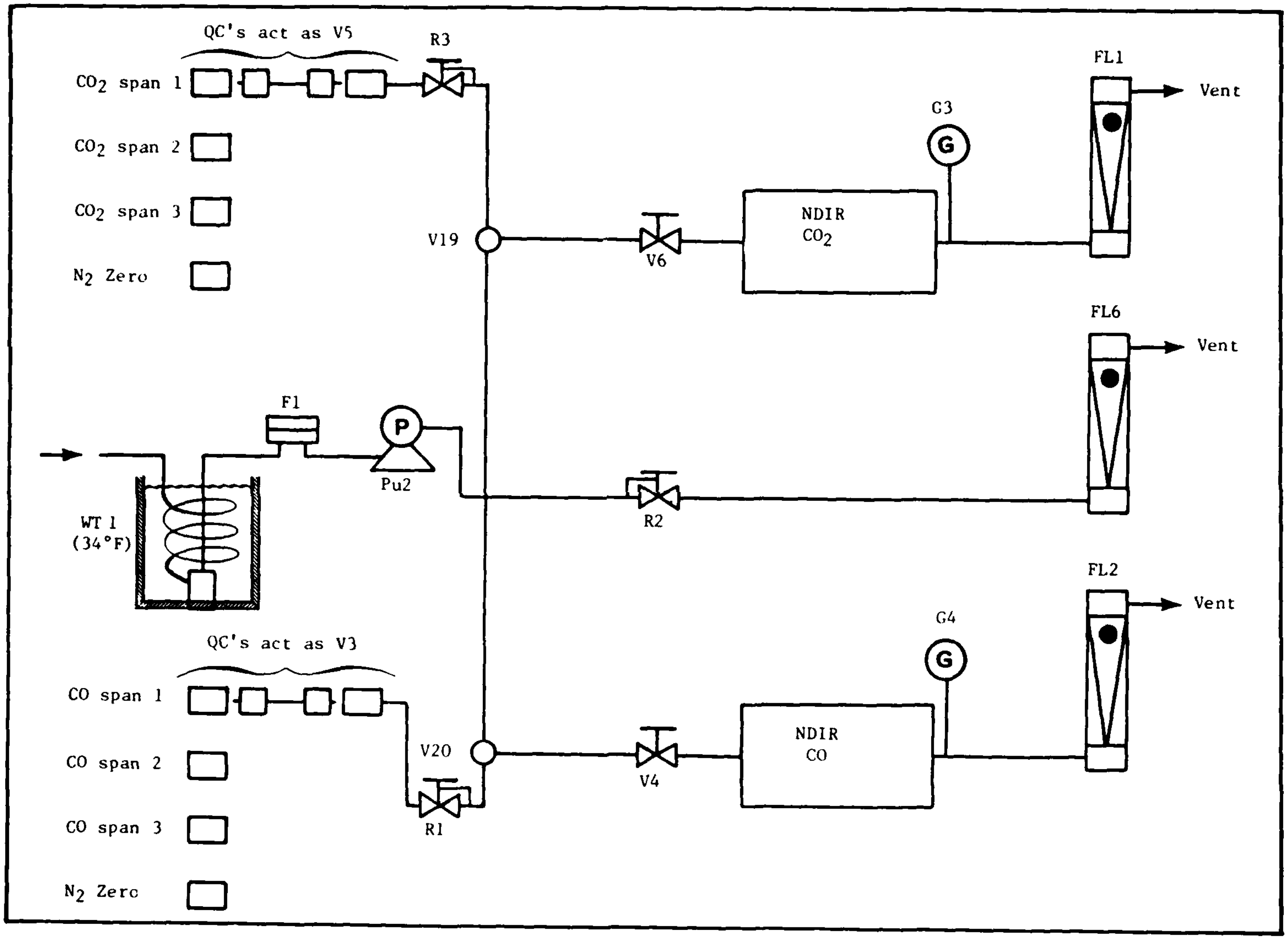


FIGURE 2-6. ANALYZER SYSTEM FOR CARBON MONOXIDE AND CARBON DIOXIDE

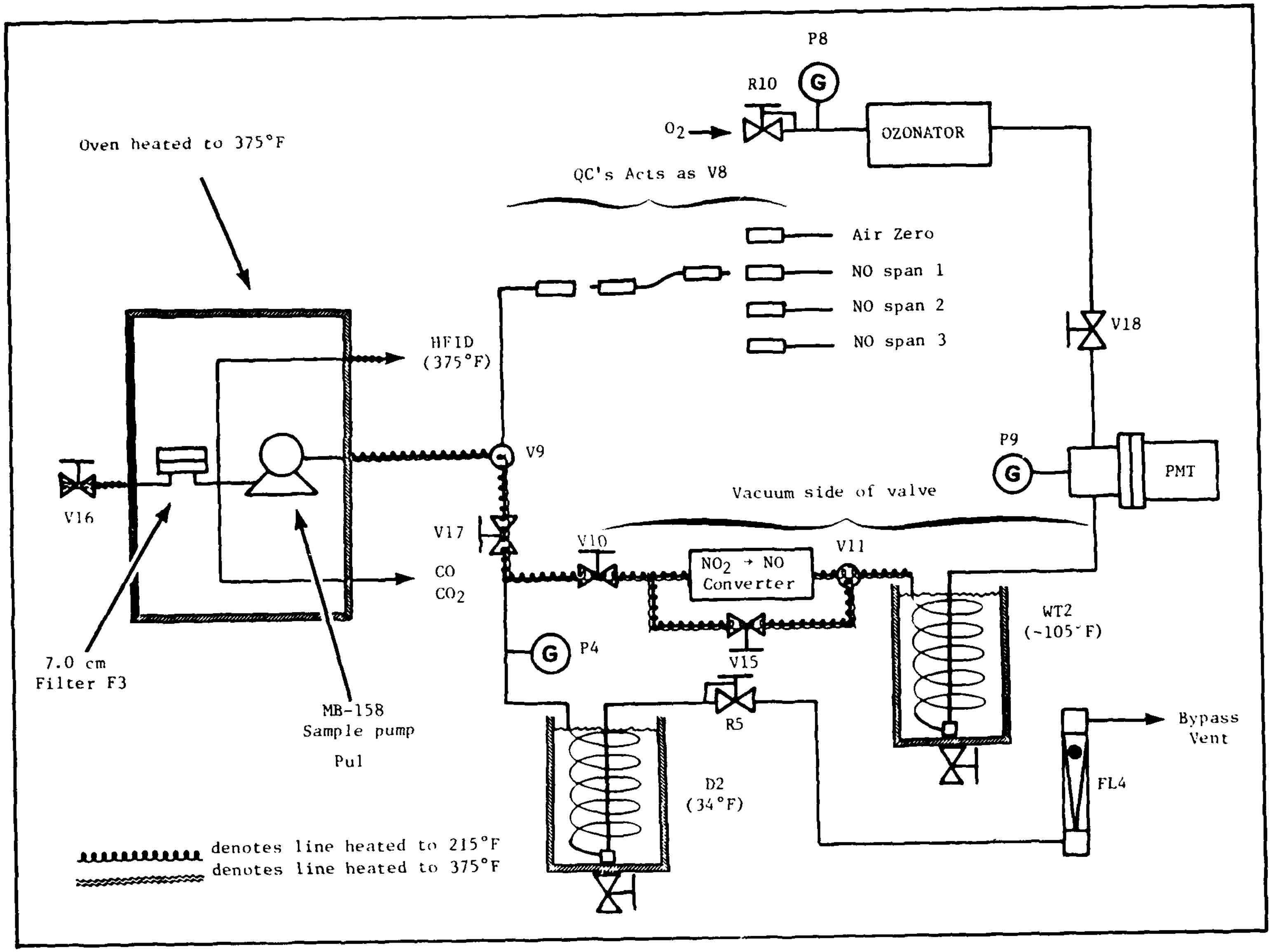


FIGURE 2-7. ANALYZER SYSTEM FOR OXIDES OF NITROGEN

TABLE 2-3. INSTRUMENTS AND RANGES ON L-4 EMISSIONS CART

Emission	Detection Method	Instrument	Range	Nominal Concentration
Carbon Monoxide (S/N AIA-23)	NDIR	Horiba OPE-15	1 2 3	0 - 1000 ppm CO 0 - 3000 ppm CO 0 - 6000 ppm CO
Carbon Dioxide (S/N 15395)	NDIR	Horiba OPE-15	1 2 3	0 - 16% CO_2 0 - 6% CO_2 0 - 2% CO_2
Oxides of Nitrogen (S/N LOAR-9691-110)	CL	TECO 10	1 2 3	0 - 250 ppm 0 - 1000 ppm 0 - 2500 ppm
Hydrocarbons (S/N 10010)	FID	Beckman 402	1 2 3	0 - 500 ppm C 0 - 1000 ppm C 0 - 5000 ppm C
Oxygen (S/N 271-001)	Polarographic	Beckman OM-11EA	1 2	0 - 25% O_2 0 - 5% O_2

TABLE 2-4. SwRI HEATED HYDROCARBON ANALYZER FLOW SCHEMATIC COMPONENT DESCRIPTION

Component	Description	Description of Function
Valve	V14	QC's act as span/zero selector valve
Valve	V13	Span/zero gas flow control valve
Valve	V12	Sample flow control valve
Gage	P5	Sample pressure
Gage	P6	HFID fuel pressure
Gage	P7	HFID air pressure
Restrictor	Rs1	Sample capillary (Beckman)
Restrictor	Rs2	HFID fuel restrictor (Beckman)
Restrictor	Rs3	HFID air restrictor (Beckman)
Detector	HFID	Beckman 402 HFID detector
Water trap	D2	Bypass flow water trap (~34°F)
Flowmeter	FL3	Bypass flowmeter (~5 CFH)
Filter	F5	7.0 cm stainless steel flip top filter
Pump	Pu3	Metal bellows MB-158 pump
Regulator	R7	Sample backpressure regulator
Regulator	R8	HFID fuel regulator
Regulator	R9	HFID air regulator

TABLE 2-5. NDIR CO AND CO_2 FLOW SCHEMATIC COMPONENT DESCRIPTION

Component	Description	Description of Function
Valve	V3	QC's act as CO selector valve V3
Valve	V4	CO flow control valve
Valve	V5	QC's act as CO_2 selector valve V5
Valve	V6	CO_2 flow control valve
Valve	V19	CO_2 sample/calibrate selector valve
Valve	V20	CO sample/calibrate selector valve
Gage	G3	CO_2 instrument pressure
Gage	G4	CO instrument pressure
Gage	P2	CO sample/span pressure
Gage	P3	CO_2 sample/span pressure
Regulator	R1	CO span/zero pressure regulator
Regulator	R2	Bypass backpressure regulator
Regulator	R3	CO_2 span/sero pressure regulator
Flowmeter	FL1	CO_2 instrument flow
Flowmeter	FL2	CO/CO_2 bypass flow
Flowmeter	FL6	CO instrument flow
Water trap	WT1	Water trap (34°F) for CO/CO_2 instrument
Filter	F1	7.0 cm stainless steel flip top filter holder
Pump	Pu2	Sample pump

TABLE 2-6. HEATED CHEMILUMINESCENT NO_x ANALYZER FLOW SCHEMATIC COMPONENT DESCRIPTION

Component	Description	Description of Oven
Valve	V8	QC's act as selector valve V8
Valve	V9	Sample/calibrate selector valve
Valve	V10	Sample flow control valve
Valve	V11	NO/NO_x selector valve
Valve	V15	NO flow control valve
Valve	V16	System leak check valve
Valve	V17	NO/NO_x total flow controller
Valve	V18	Ozone flow control valve
Gage	P4	Sample backpressure
Gage	P8	Oxygen pressure gage
Gage	P9	Reaction chamber vacuum
Flowmeter	FL4	Sample bypass flowmeter
Regulator	R5	Sample backpressure regulator
Regulator	R10	Oxygen pressure regulator
Dryer	D2	Bypass flow water trap (~34°F)
Water Trap	WT2	NO_x/NO water trap (IPA•CO_2 @ -105°F)
Filter	F3	7.0 stainless steel flip top filter holder
Pump	Pu1	Sample pump

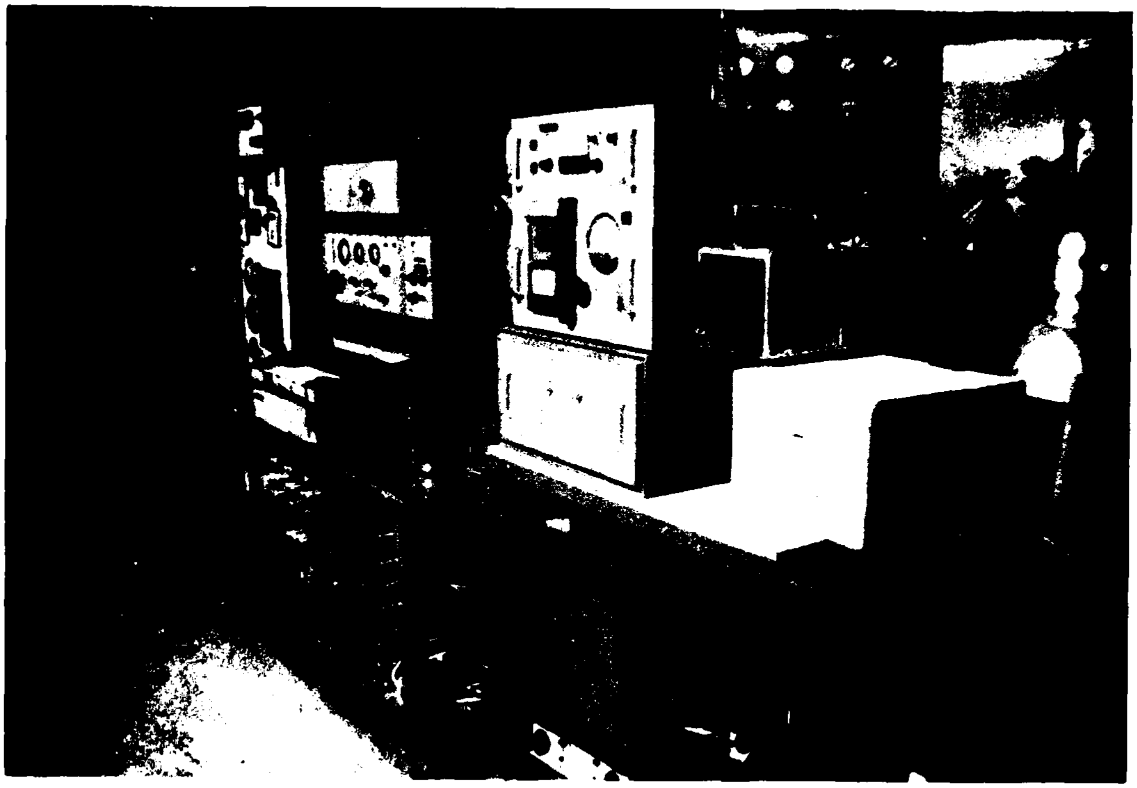


FIGURE 2-8. EMISSION INSTRUMENT CONSOLE, FRONT VIEW

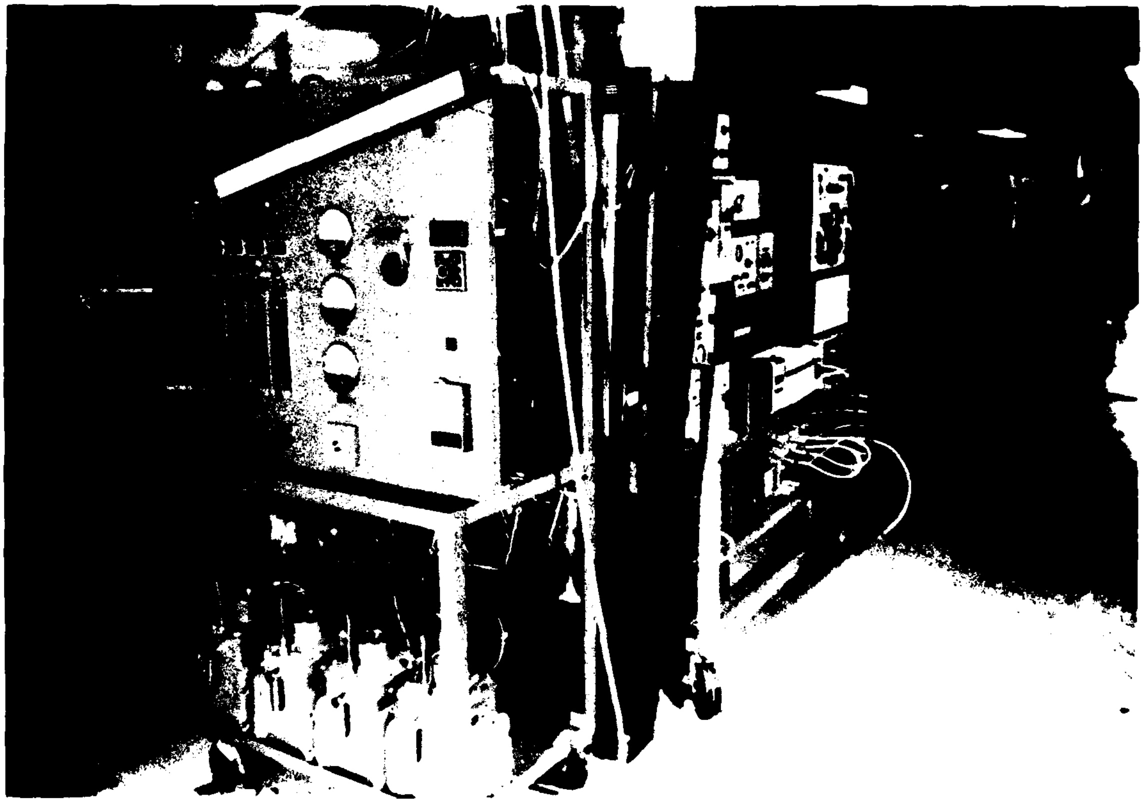


FIGURE 2-9. EMISSION INSTRUMENT CONSOLE, END VIEW

Measurements of exhaust particulate emissions were obtained during some of the tests of the Detroit Diesel engine. The primary tool utilized for this series of measurements was a dilution tunnel of the type shown in Figures 2-2 and 2-10; the dilution of the sample stream is utilized for cooling and mixing prior to the accumulation of a particulate sample. In order to obtain a sample of the exhaust, probes were located in each of the engine exhaust ducts at a point downstream from the turbocharger outlets. A regulating valve was located in each sample line, and the pressure drop across the valve was used as a means of equating the sample line flow rates. Thus, a single sample representative of both engine exhaust ducts was obtained and supplied to the particulate tunnel. The tunnel had a nominal diameter of eight inches, and air flow rates sufficient for a dilution ratio of 10 to 20 were utilized. Within the tunnel, the exhaust sample was mixed with the dilution air and cooled to 125°F. A metered sample of the diluted stream was obtained and applied to a 47 millimeter Pallflex T60A20 filter that was weighed prior to the beginning of the test. Subsequent weighing, along with the measured flow of the air stream, allowed the calculation of the particulate weight per standard cubic foot of engine exhaust. In general, only one sample filter was used during this test series; the multiple filters shown in Figure 2-10 would be utilized when more elaborate analyses of the particulate matter were required.

2.2 TEST PROCEDURE

The general philosophy that governed the performance of the alternate fuel tests was closely related to the ultimate use of fuel-water emulsions on USCG cutters; thus, it was desired to obtain data that would be representative of boat operation. A sample of engine speeds and loads was obtained for one USCG cutter powered by Cummins engines, and the prop load curve for the engine was calculated. This curve is shown, along with the engine maximum output, in Figure 2-11. The specific test points for consideration during the evaluation program were selected from locations along the prop load curve.

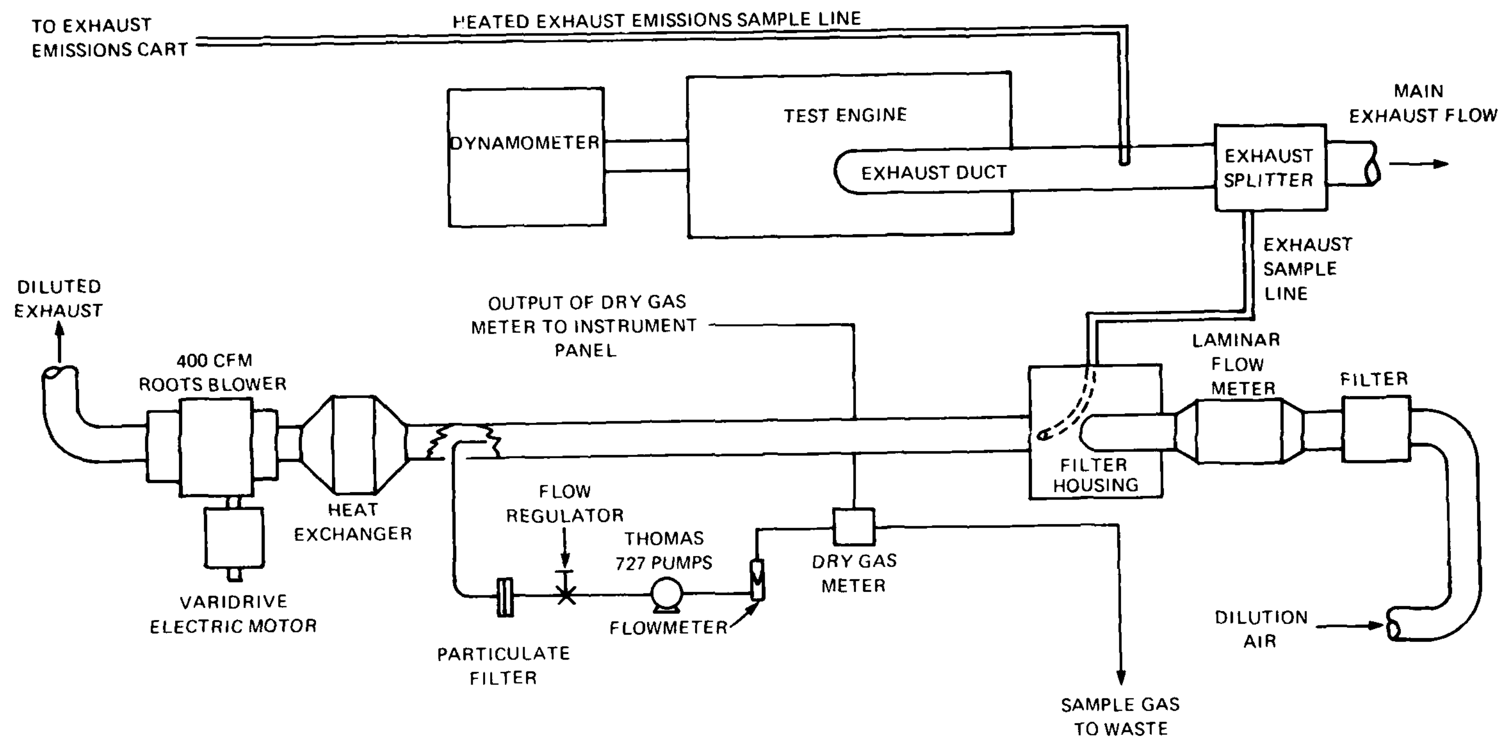


FIGURE 2-10. PARTICULATE MEASURING SYSTEM

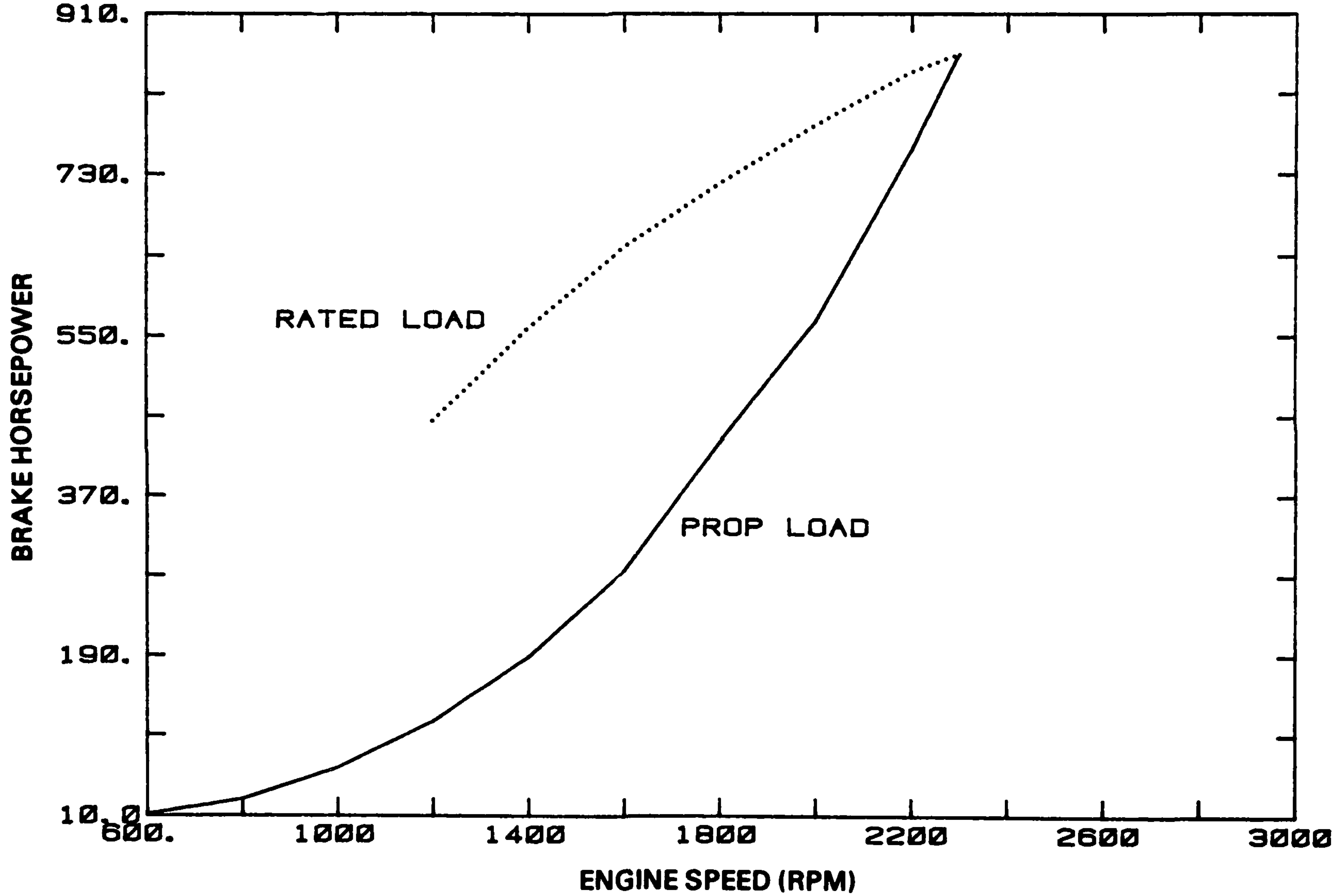


FIGURE 2-11. ENGINE SPEED AND POWER OUTPUT, MAXIMUM HORSEPOWER AND PROP LOAD, CUMMINS ENGINE

In order to establish appropriate test points for comprehensive evaluation, records representative of over 4900 hours of operation of 14 cutters powered by Cummins engines were evaluated. Figure 2-12 shows engine speed plotted against the percentage of the total operating time that was spent at each speed. It is apparent from this representation that engine speeds of 1200 and 1800 rpm are particularly important during boat operation; a fuel system designed for conservation of diesel fuel should exhibit a significant effect at these speeds in order to be effective from an overall viewpoint. The most comprehensive testing, therefore, was performed at speeds of 1200 and 1800 rpm and the prop load associated with each speed. In addition, some test data were obtained at 900 rpm and prop load.

For the tests involving the Detroit Diesel engine, the propeller load curve supplied by the manufacturer for the 16V-149TI engine was used. The loads were multiplied by 0.75 in order to account for the difference in the number of cylinders between the test engine and the marine engine; the result is shown in Figure 2-13. Tests were performed at 200 rpm increments along the prop load curve, but the comprehensive evaluation of specific points was not conducted. No data was available to evaluate the 95-ft. WPB duty-cycle with Detroit Diesel engines.

The procedure used during each test run began with a check of the instruments associated with data acquisition. In each case calibrations were performed as required. The engine was started and allowed to warm up, and then the speed and load selected for that day of testing were established by adjusting the diesel fuel-flow rate and the dynamometer controller. The initial engine operation was performed with clear No. 2 diesel fuel having specifications as shown in Appendix A, and baseline data were recorded prior to the introduction of water into the fuel system.

Upon completion of the baseline data acquisition, a water flow appropriate to a five percent concentration was initiated. The dynamometer load was adjusted to the prop load test point by adjusting the output of the engine fuel pump, and a sample of the emulsion was obtained for verification of water concentration. Data were recorded at the five percent concentration;

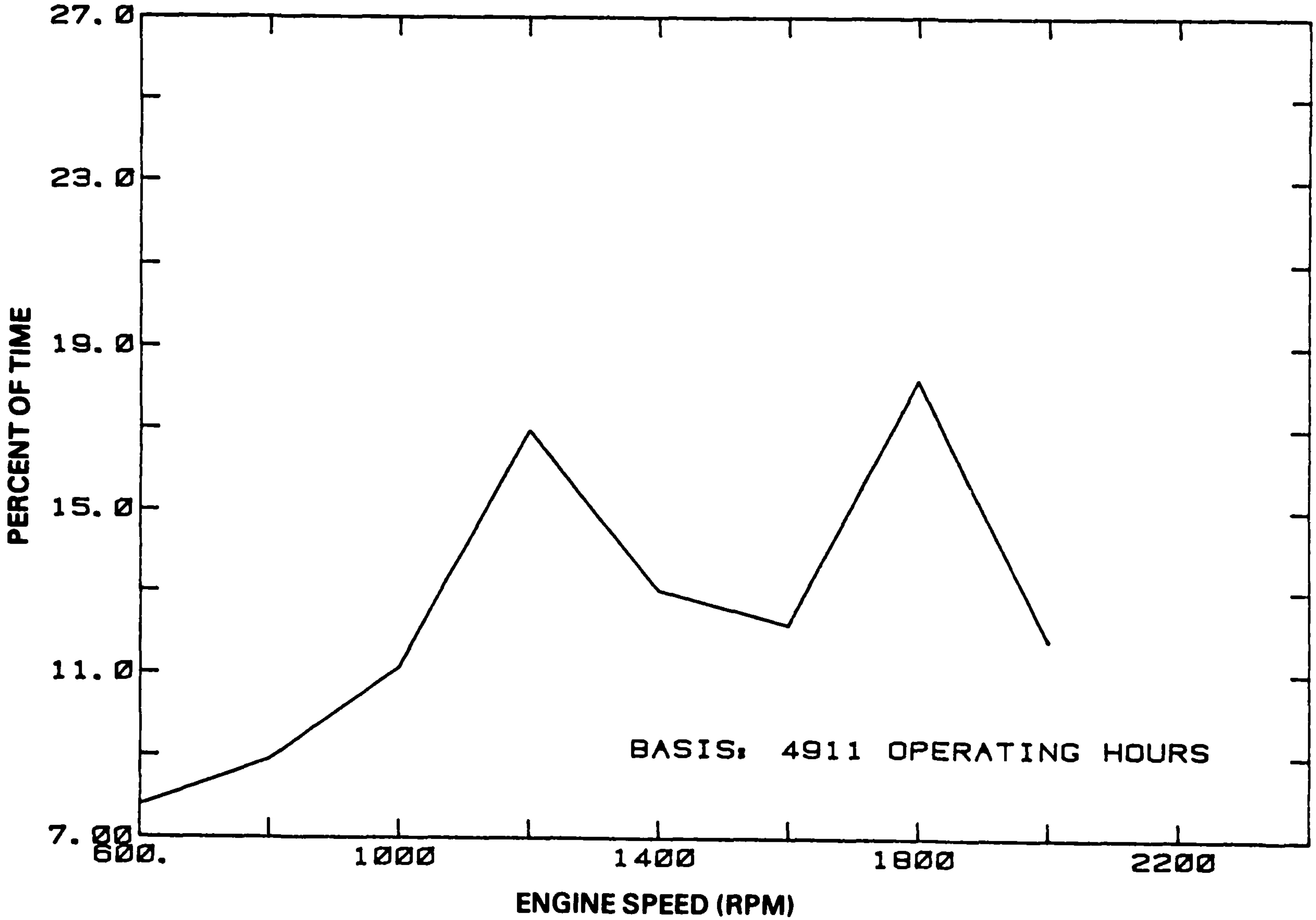


FIGURE 2-12. OPERATING TIME AS FUNCTION OF ENGINE SPEED FOR CUMMINS ENGINE-POWERED CUTTERS

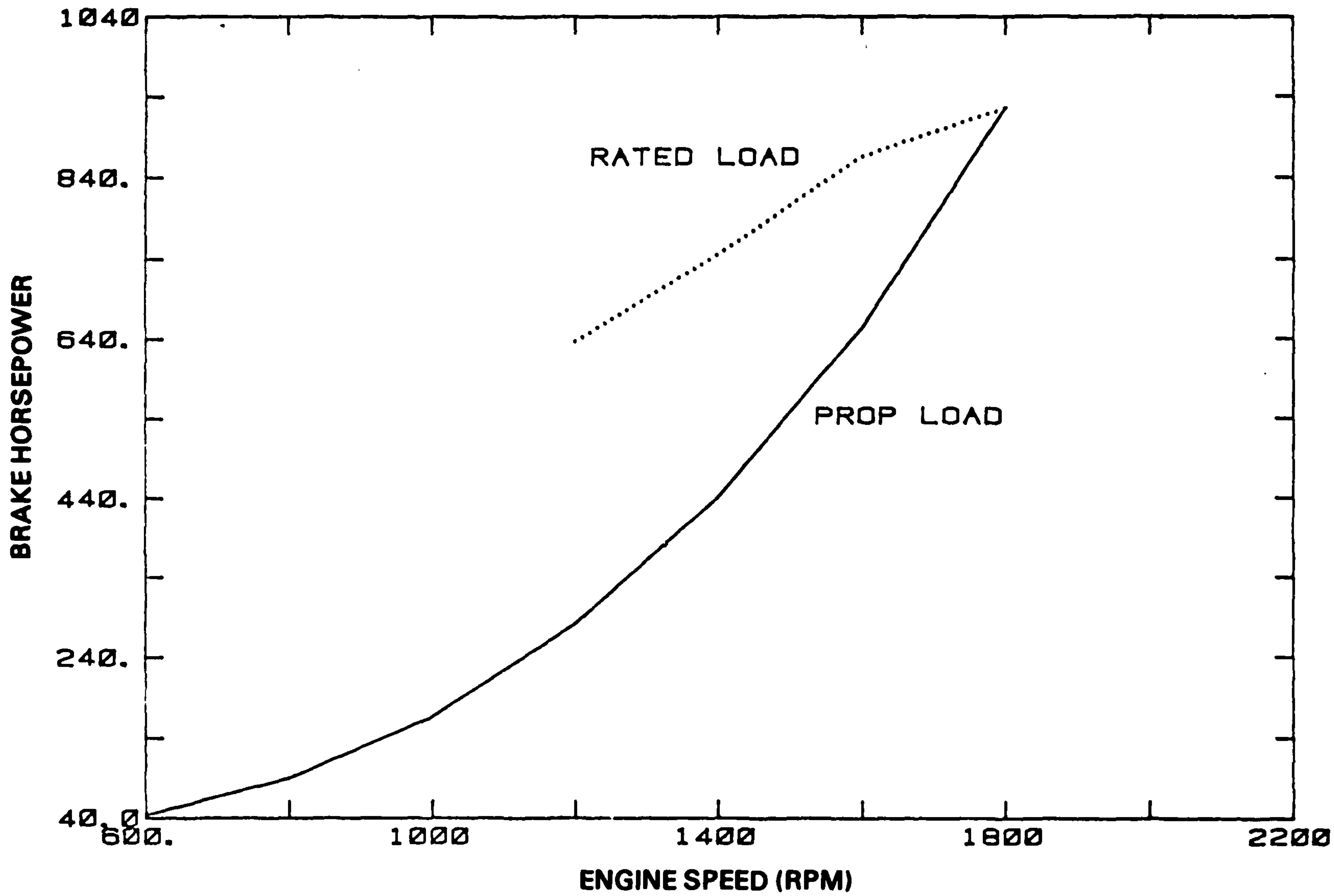


FIGURE 2-13. ENGINE SPEED AND POWER OUTPUT, MAXIMUM HORSEPOWER AND PROP LOAD, DETROIT DIESEL TWELVE-CYLINDER ENGINE

this process involved repeated measurements of the fuel rate. This sequence was then repeated at water concentrations of 10, 15, 20, and 25 percent by volume. Upon completion of the test run at the highest water concentration, the fuel system was flushed with clear diesel fuel, and the baseline test run was repeated. Subsequent days of testing involved repetition of this entire process at other speed and load conditions.

All data were recorded on a permanent record sheet, and individual values were subsequently introduced into a computer data reduction program.

2.3 DATA REDUCTION AND CALCULATIONS

A computer routine was utilized for the calculation of performance quantities and for the comparison of data obtained under the same operating conditions. A set of sample calculations is included in Appendix B. The sample calculations reflect the computations made by the computer program for each test run.

The basic performance quantities, such as horsepower, torque, and specific fuel consumption, were calculated using conventional relationships and constants appropriate to the specific instruments employed. These basic parameters are listed, along with measured quantities, in the tabulations of the results shown in Appendix C.

At the test points described by 1200 rpm and 1800 rpm for the Cummins engine, the test sequence over the spectrum of water concentrations was repeated several times in order to build a statistical basis for the data. Thus, a single point, such as 1200 rpm and 15 percent water, was evaluated on several test days, and three to five individual runs were performed at that point. Since each individual test run included several fuel rate measurements, the flow rate of diesel fuel specified for each run in Appendix C represents an average of several measurements. These averages for each run were then included in an overall average applicable to each test point defined by speed, load, and water concentration.

The raw data from the emission measurement procedures was interpreted through calibration curves developed for each instrument in terms of the concentration of the contaminant species in the exhaust stream. The values for each test run are reported in terms of parts per million or percent in Appendix C. During each test run for which emissions were measured, the data on exhaust emissions allowed the calculation of a carbon balance fuel-air ratio. This value was compared to the fuel-air ratio obtained by direct measurement of fuel flow rate and air flow rate. The results of the comparison for the Cummins engine are shown in Figure 2-14, which describes the error between the two values using the measured value as a standard. It should be noted that the Federal procedure for certification of diesel engines allows a tolerance of 10 percent in the comparison between calculated and measured fuel-air ratios.

During both the Cummins and GM engine tests, comprehensive data were obtained at selected test points. The average diesel fuel flow rate at each test point defined by speed, load, and water concentration was obtained from the collection of fuel rates for the individual test runs. Then, the standard deviation at each test point was calculated. As a further step, a 90 percent confidence band was calculated for each test point using the Student's t-distribution. This step allowed an indication of the significance that could be attached to the test results. The percentage change in diesel fuel flow rate was then calculated for each test point using the zero water concentration data as the baseline for each test point.

A further statistical test based upon the Student's t-distribution was applied to the fuel consumption data. For those test points where the presence of water indicated a significant change in diesel fuel consumption, a test was applied which measured the confidence with which it could be stated that the mean of the fuel consumption measurements was, in fact, different from the mean of the fuel flow measurements at zero water concentration. The results of this test allow the attachment of a numerical confidence to the statement that the presence of water in the fuel actually causes a change in the flow rate of diesel fuel.

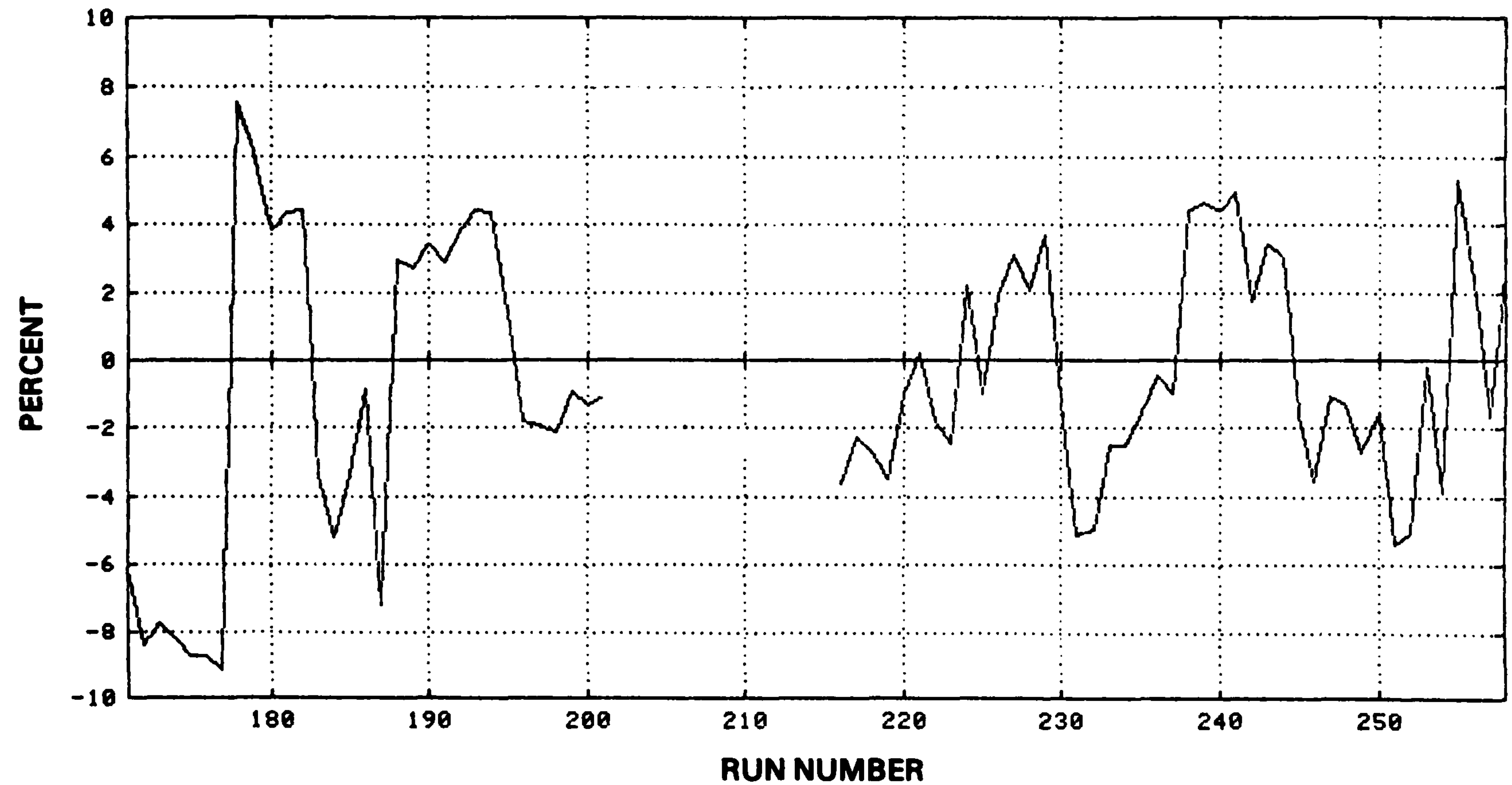


FIGURE 2-14. COMPARISON OF CARBON BALANCE AND MEASURED FUEL-AIR RATIO, CUMMINS ENGINE TESTS

3. RESULTS

The results of the testing program are phrased in terms of fuel consumption, smoke, gaseous emissions, and engine operating parameters. Each of these qualities are discussed in detail in the following sections.

3.1 FUEL CONSUMPTION

The primary thrust of the entire program was an assessment of the effect of water in the fuel on the quantity of diesel fuel consumed by the engine at a particular speed and load. The fuel consumption results, therefore, are of particular interest in the context of the overall program goals.

The fuel consumption measurements at the 1800 rpm prop load test point for the Cummins engine are shown in Figure 3-1. The solid curve is drawn through the mean values of all test runs at each water concentration, and the 90 percent confidence band is shown by broken lines. The curve indicates that the maximum effect of the presence of water was obtained at a concentration of 20 percent by volume, where the 20 percent figure represents the comparison between water volume and the total volume of liquid entering the engine. With 20 percent water present in the fuel, the diesel fuel flow rate was reduced by 1.7 percent by comparison with the flow rate of clear diesel fuel without water addition. The statistical analysis allows the statement that a 95 percent confidence exists that the means of the test runs at zero percent water and 20 percent water are actually different. Or, in other words, there is a 95 percent confidence that the sample populations at zero percent water and 20 percent water are different, and the observed change did in fact occur.

Results for the test runs at 1200 rpm and prop load are shown in Figure 3-2. The presentation format is identical to that used for the 1800 rpm tests. In this case, the minimum diesel fuel consumption occurred at a water concentration of 15 percent, and the reduction in diesel fuel flow by comparison to test runs during which no water was added was 3.3 percent. Again, a 95 percent confidence exists that the mean values of the samples

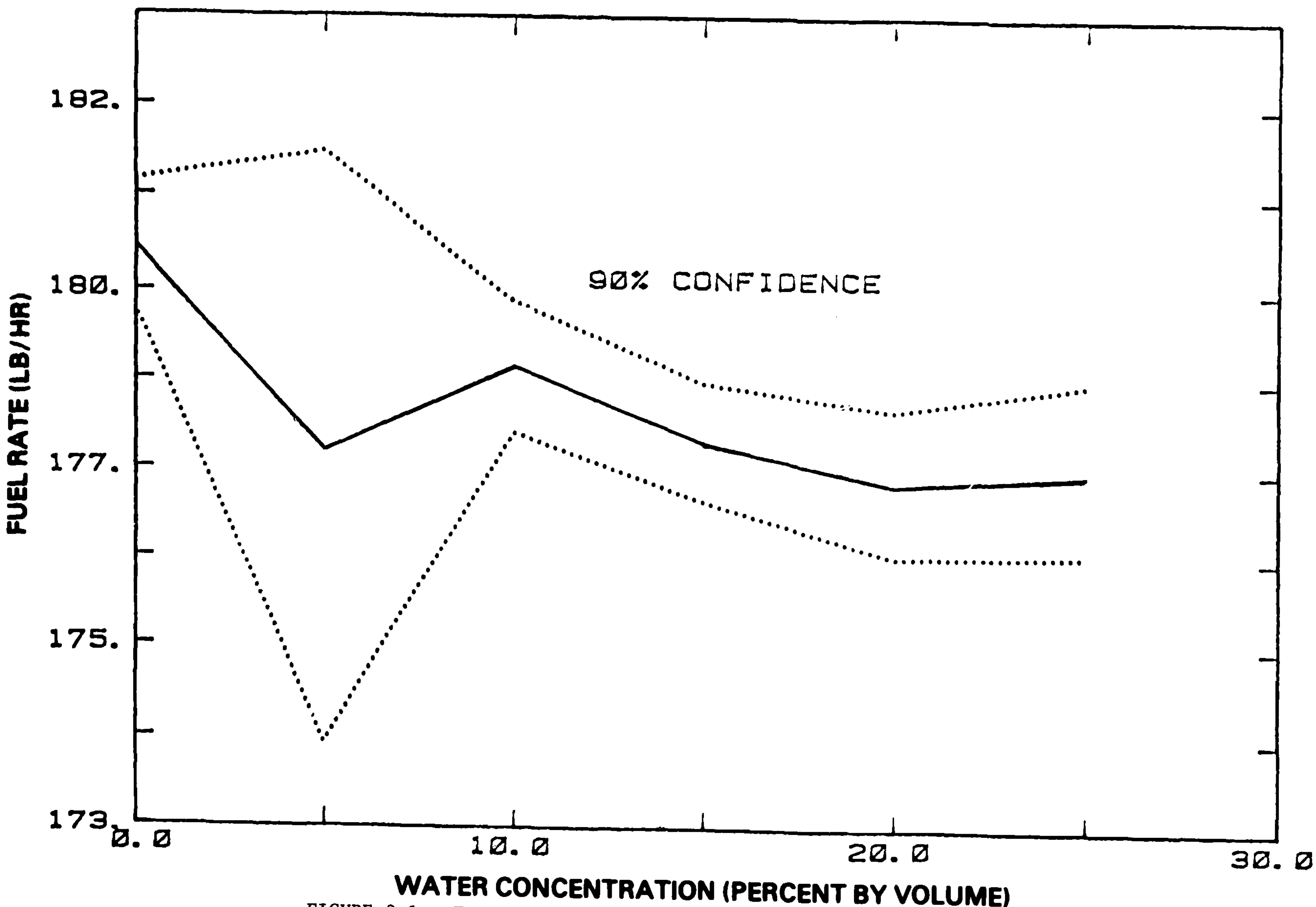


FIGURE 3-1. FUEL CONSUMPTION, CUMMINS ENGINE, 1800 RPM

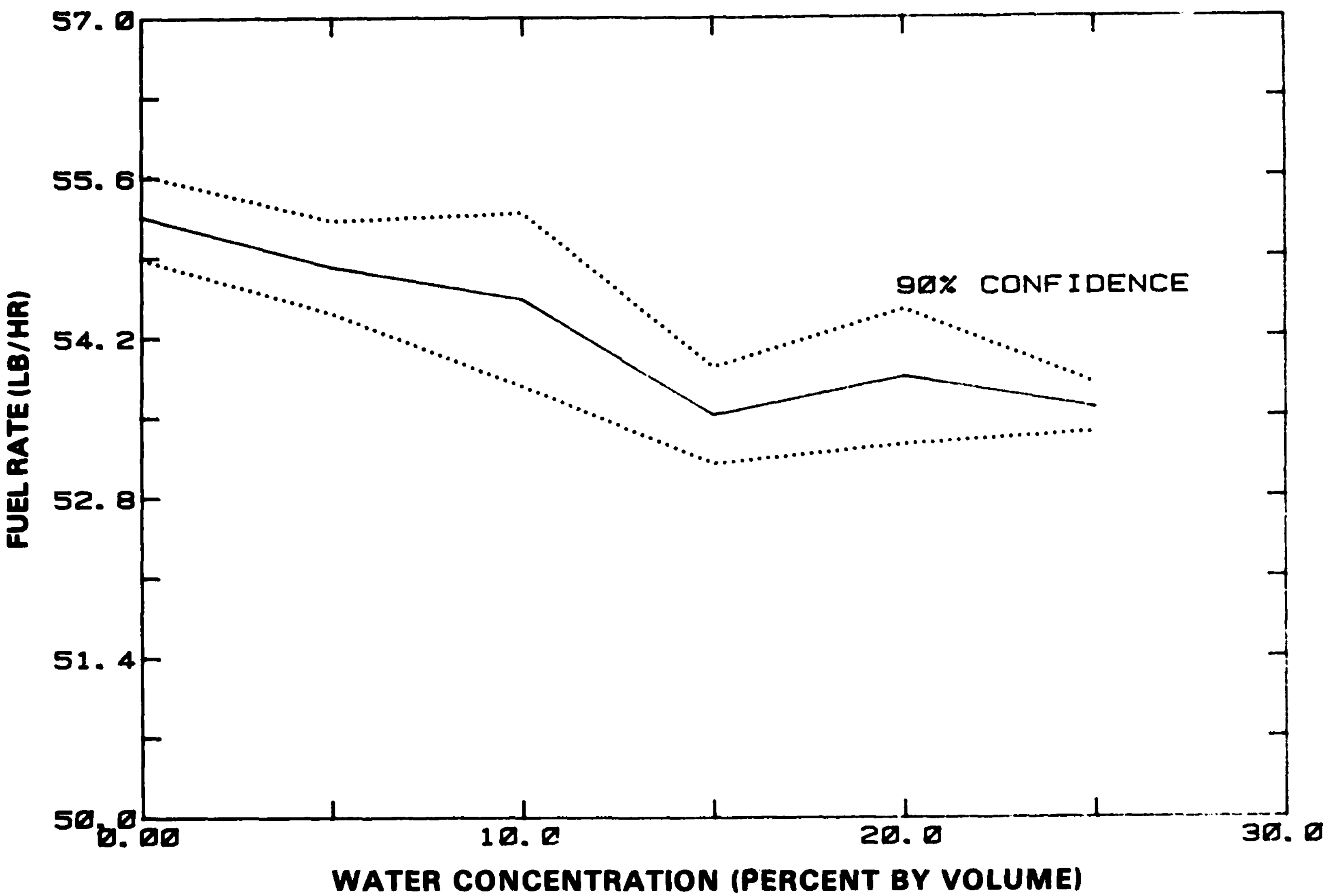


FIGURE 3-2. FUEL CONSUMPTION, CUMMINS ENGINE, 1200 RPM

obtained without water addition and with 15 percent water addition in fact represent different populations.

Some data were obtained for evaluation of the effect of water addition on fuel consumption at a speed of 900 rpm and prop load. The results are shown in Figure 3-3, using the same format as that described above. During these tests the reduction in diesel fuel flow was found to be 2.5 percent.

For the Detroit Diesel engine, fuel consumption results were obtained at several points along the prop load curve. At the 1000 rpm test point, the body of data was sufficiently extensive to allow statistical analysis; the results are shown in Figure 3-4. For this case, the general tendency was for the water to increase fuel consumption. The same trend was observed for the tests conducted at other speeds; the results are shown in Figure 3-5. No significant improvement in the rate of diesel fuel consumption could be inferred from these tests.

The configuration of the Detroit Diesel engine did allow an assessment of the effect of injection timing on the performance of water-in-fuel emulsions. Since the timing change can be effected through an injector adjustment, rather than a camshaft change, it was possible to obtain data at several values of the injection timing. Figure 3-6 describes the relationship between the fuel injector adjustment dimension and injection timing; the standard value for the engine was 2.205 inches. Tests were performed for values of the beginning of injection from about 25° BTDC to about 15° BTDC; the specific dimensions and timing angles are shown in Table 3-1. Most of the tests were performed at 1000 rpm, and examination of Figure 3-7 indicates that the timing change did not affect the relationship between fuel consumption and water addition. One series of tests was performed at 1400 rpm (Figure 3-8); the results again indicate that the timing change did not improve the ability of the engine to benefit from the addition of water to the fuel. In both Figure 3-7 and Figure 3-8, the curves designated as baseline are reproduced from Figures 3-4 and 3-5.

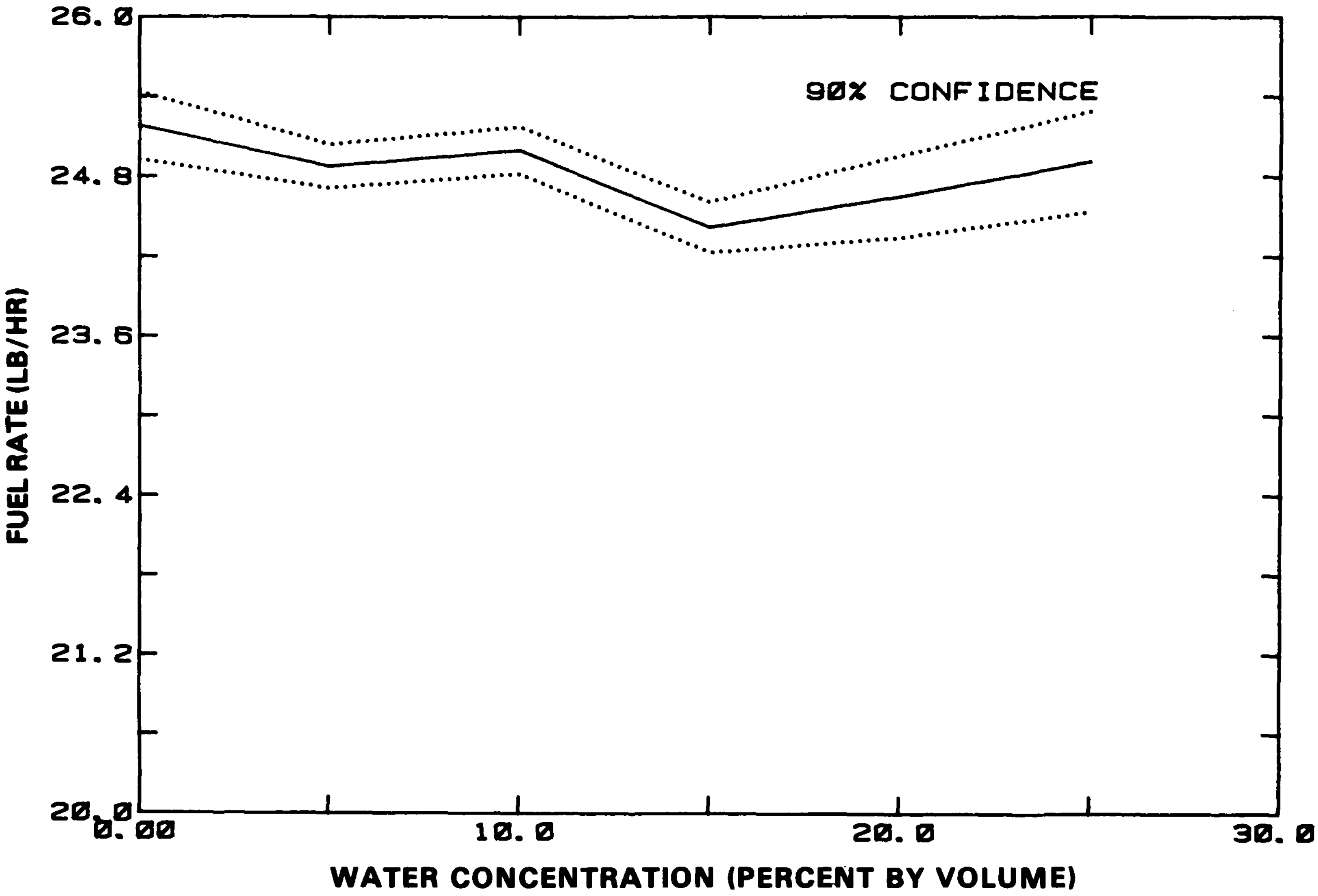


FIGURE 3-3. FUEL CONSUMPTION, CUMMINS ENGINE, 900 RPM

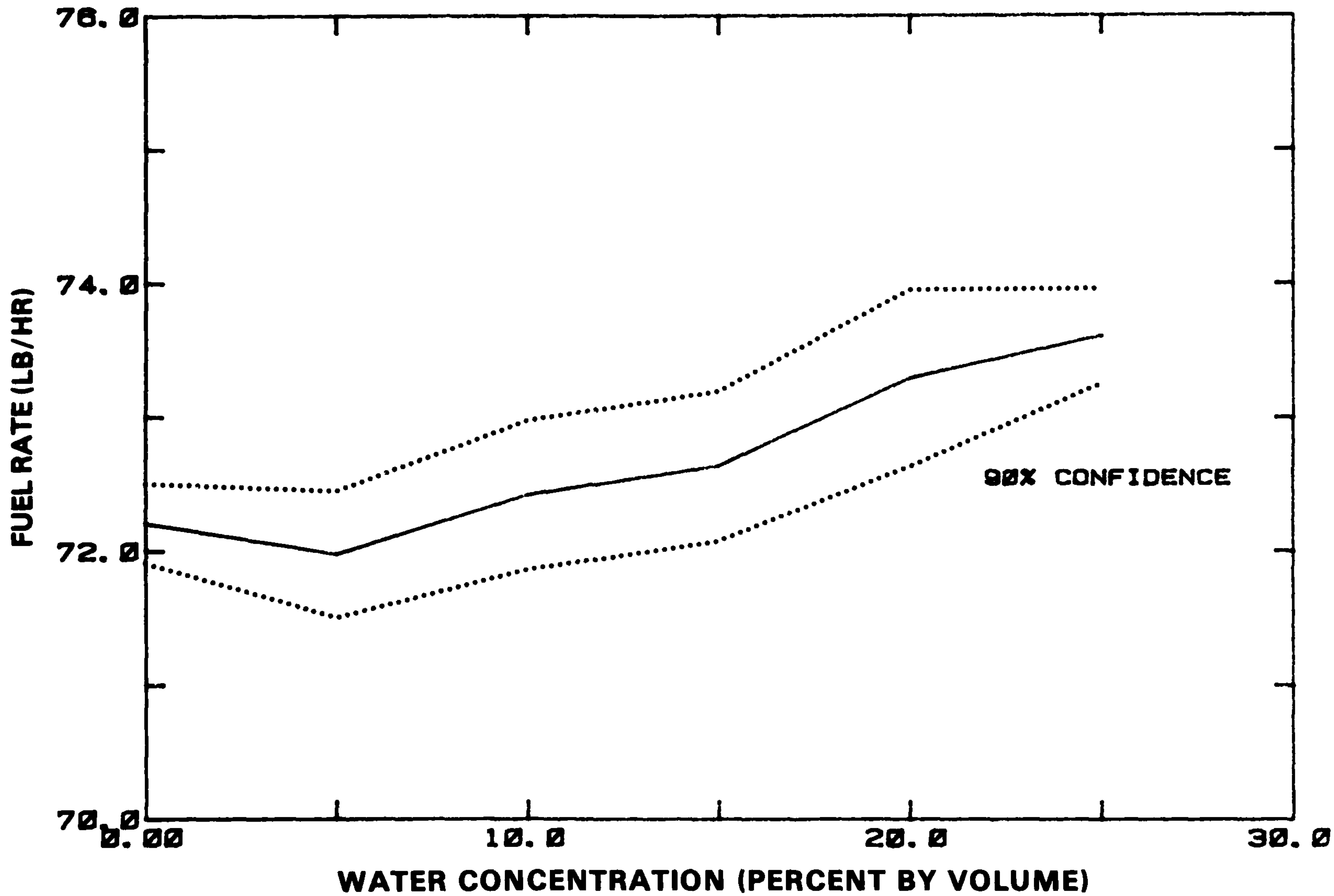


FIGURE 3-4. FUEL CONSUMPTION, DETROIT DIESEL ENGINE, 1000 RPM

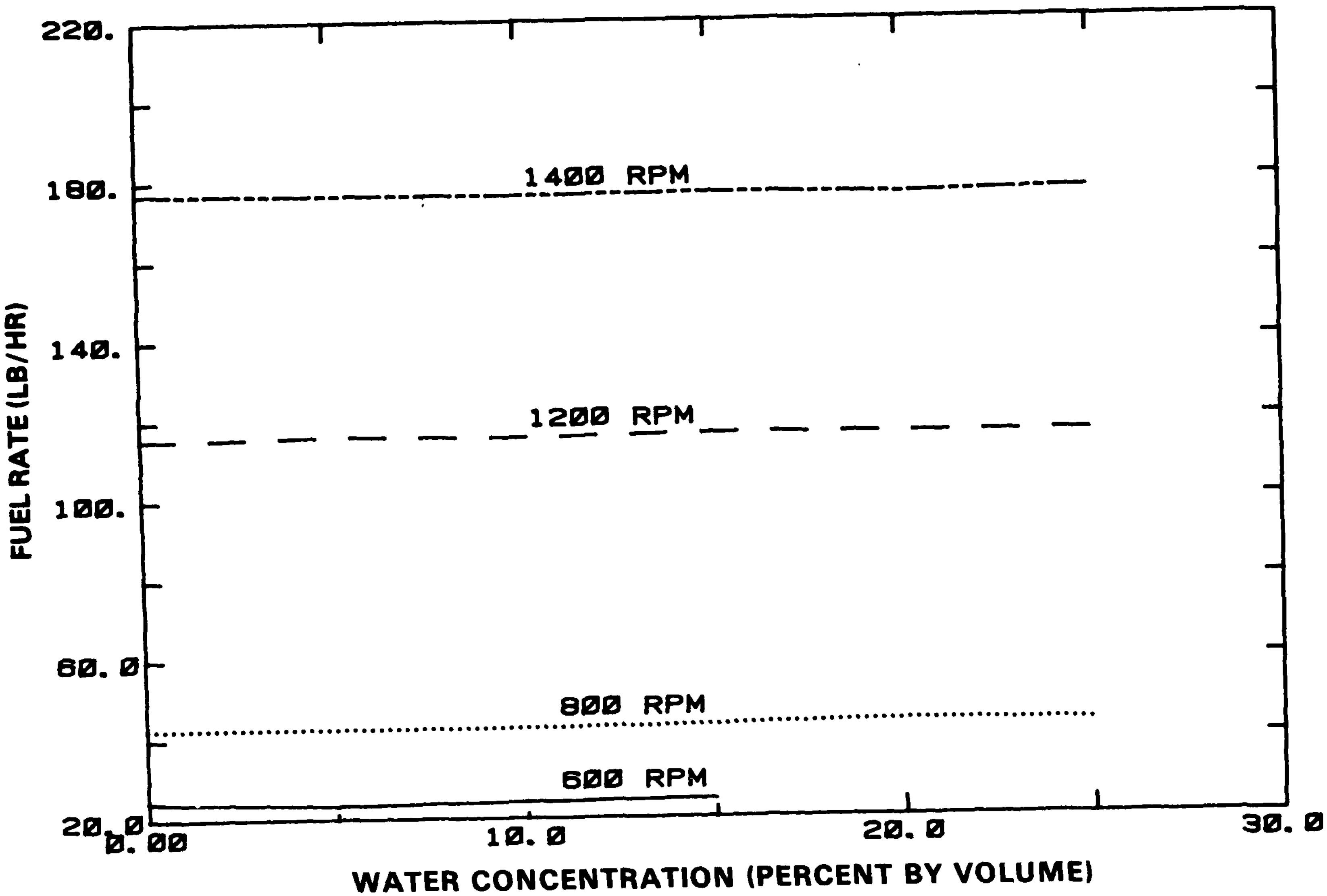


FIGURE 3-5. FUEL CONSUMPTION, DETROIT DIESEL ENGINE, FOUR SPEEDS

TABLE 3-1. DETROIT DIESEL 12V-149TI ENGINE FUEL INJECTION TIMING

Injector Adjustment Dimension (inches)	Timing of Injection Event (degrees)
2.165	5.5 advance
2.185	2.8 advance
2.205	0
2.223	2.4 retard
2.235	4.1 retard

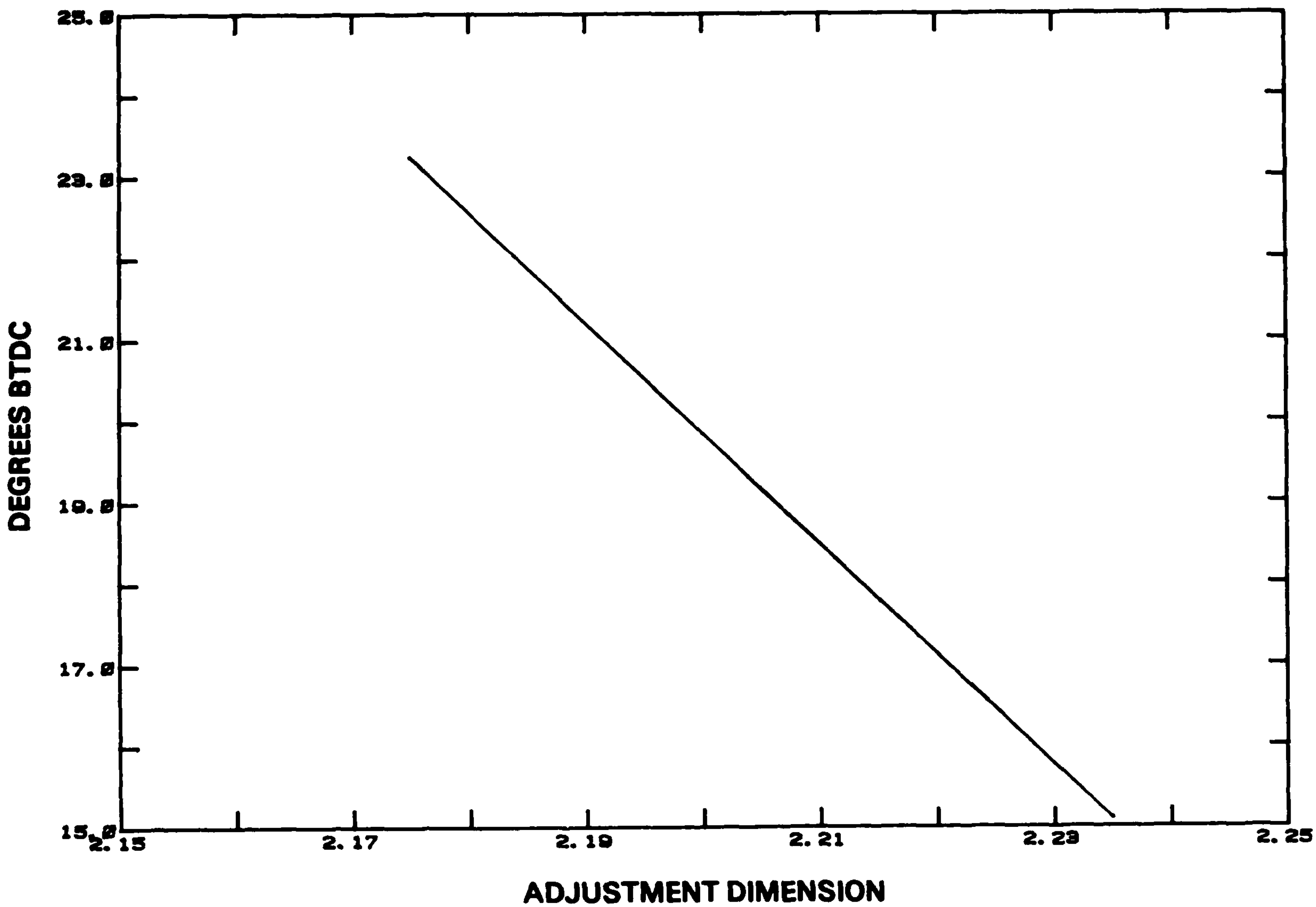


FIGURE 3-6. FUEL INJECTION TIMING AS FUNCTION OF ADJUSTMENT DIMENSION, DETROIT DIESEL ENGINE, 12V-149TI (180 INJECTORS)

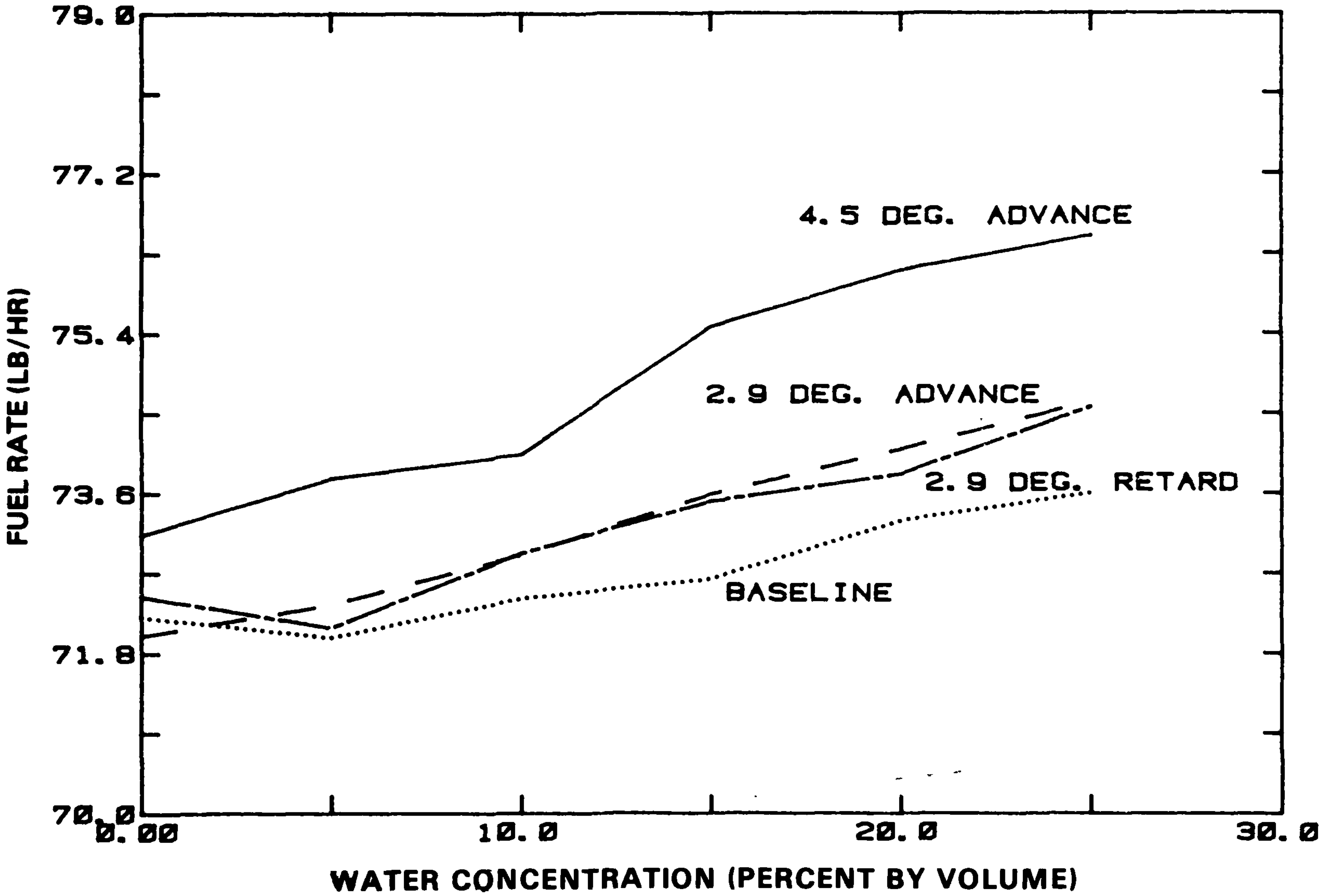


FIGURE 3-7. EFFECT OF INJECTION TIMING ON FUEL CONSUMPTION, DETROIT DIESEL ENGINE, 1000 RPM

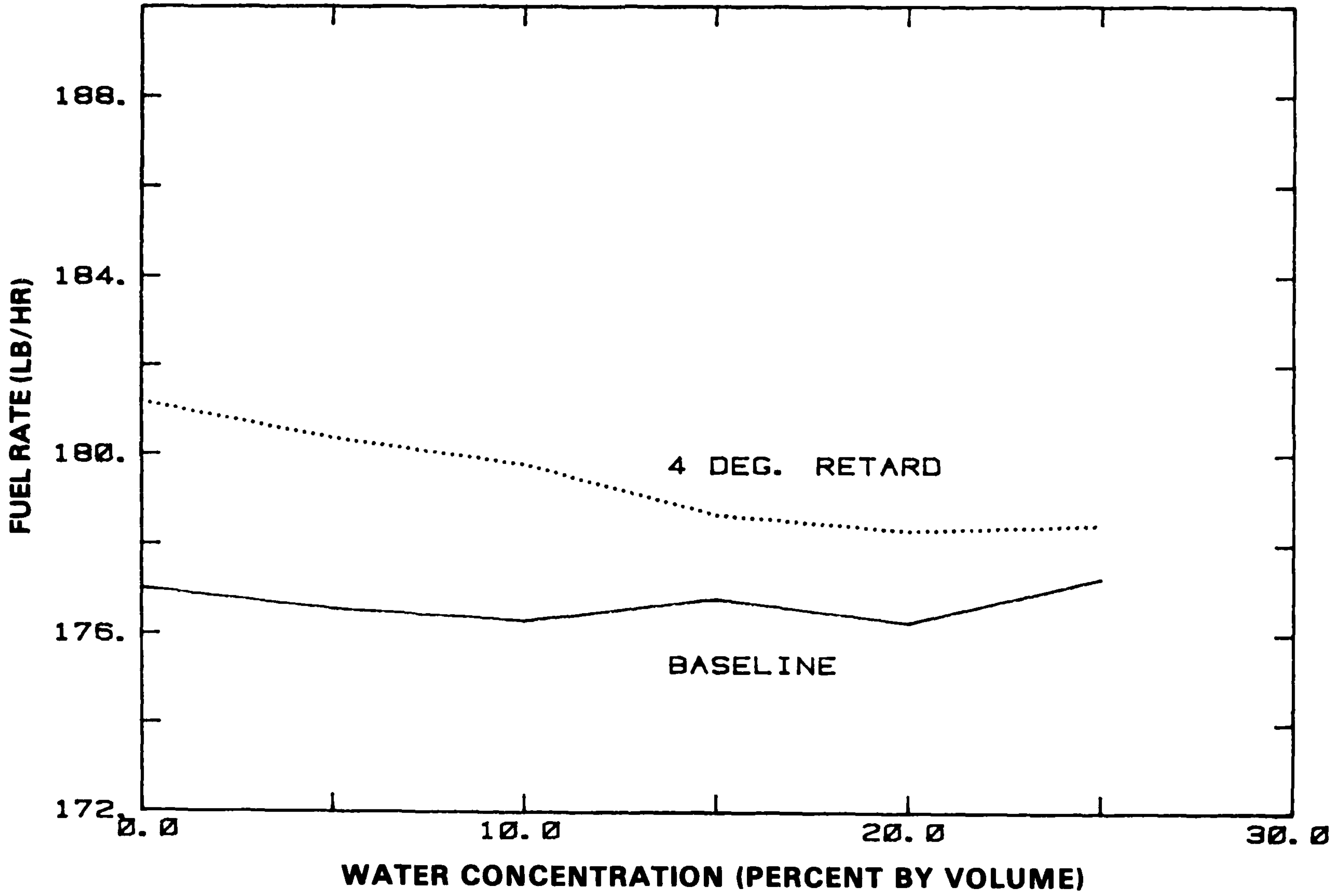


FIGURE 3-8. EFFECT OF INJECTION TIMING ON FUEL CONSUMPTION, DETROIT DIESEL ENGINE, 1400 RPM

3.2 EXHAUST SMOKE

During the performance of the test runs on the Cummins engine, it was observed that the presence of water in the fuel caused a significant percentage reduction in the presence of exhaust smoke. The test results are shown in Figure 3-9 for the test point at 1800 rpm, and in Figure 3-10 for the test run at 1200 rpm. In both cases, it may be observed that the smoke reduction increased as water was added to the fuel. Although the percentage reductions are dramatic, it must be noted that the opacity of the exhaust stream was quite low even without water addition. Therefore, the effect of water addition on smoke reduction is questionable from a practical viewpoint, although the magnitude of the effect is statistically significant.

3.3 PARTICULATE EMISSIONS

During some of the Detroit Diesel engine tests, measurements were made of the particulate emissions using the procedures outlined in Section 2. A sample of the exhaust was obtained from each of the engine exhaust pipes, diluted with air, and passed through a pre-weighed filter. The difference in filter weights, combined with gas flow measurements, provided an assessment of the particulate loading per standard cubic foot of exhaust.

The results obtained from the particulate measurements are shown in Figures 3-11 and 3-12 as a function of both water concentration and engine speed. It may be observed from the data presented that the addition of water to the fuel has no positive effect on the particulate emissions.

3.4 OXIDES OF NITROGEN

The potential of water addition in terms of reduction of emissions of oxides of nitrogen from an operating engine was of particular interest at the outset of the program; other investigators have suggested that the use of water-in-fuel emulsions can provide a significant change in the emission levels of this particular contaminant.

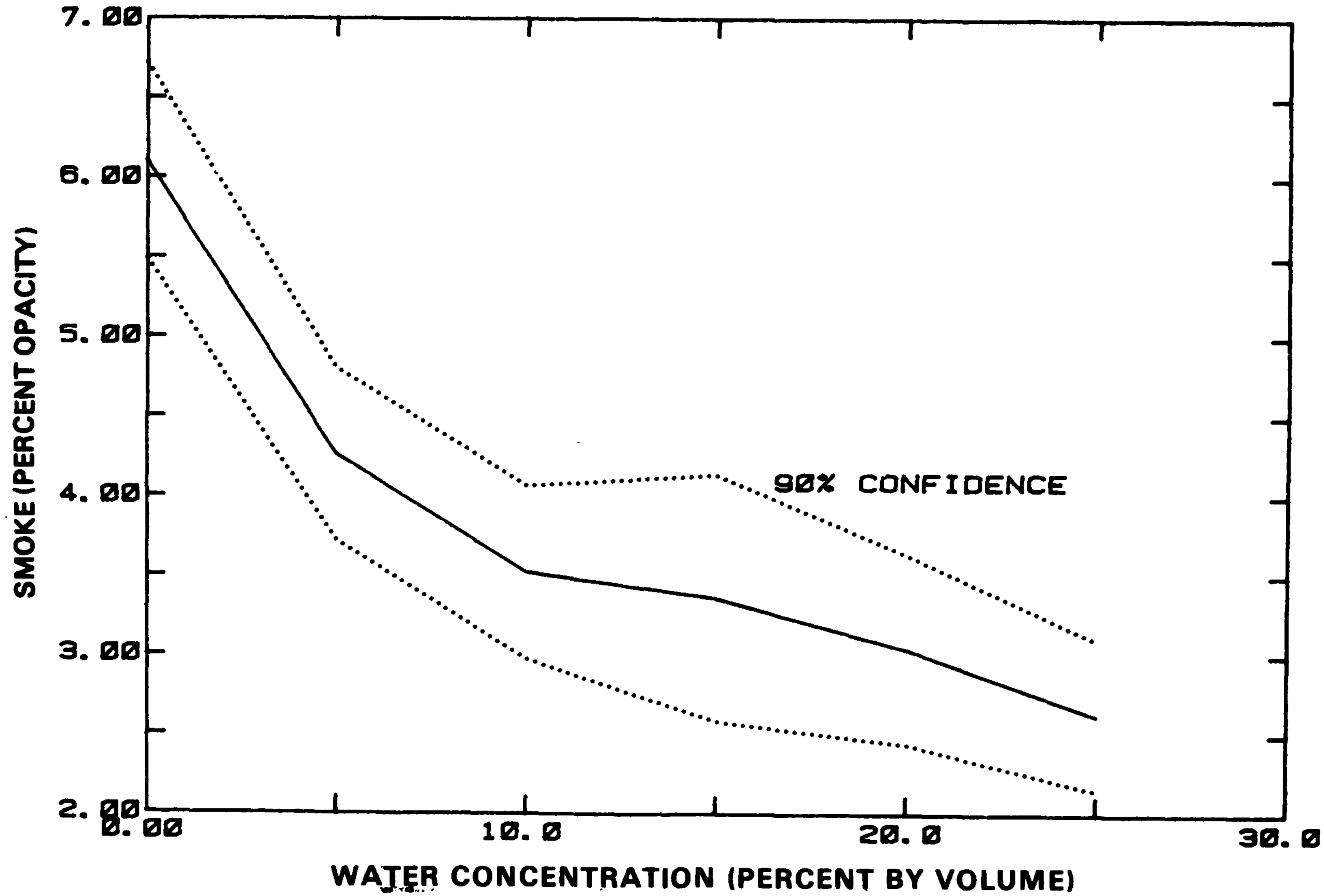


FIGURE 3-9. EXHAUST SMOKE, CUMMINS ENGINE, 1800 RPM

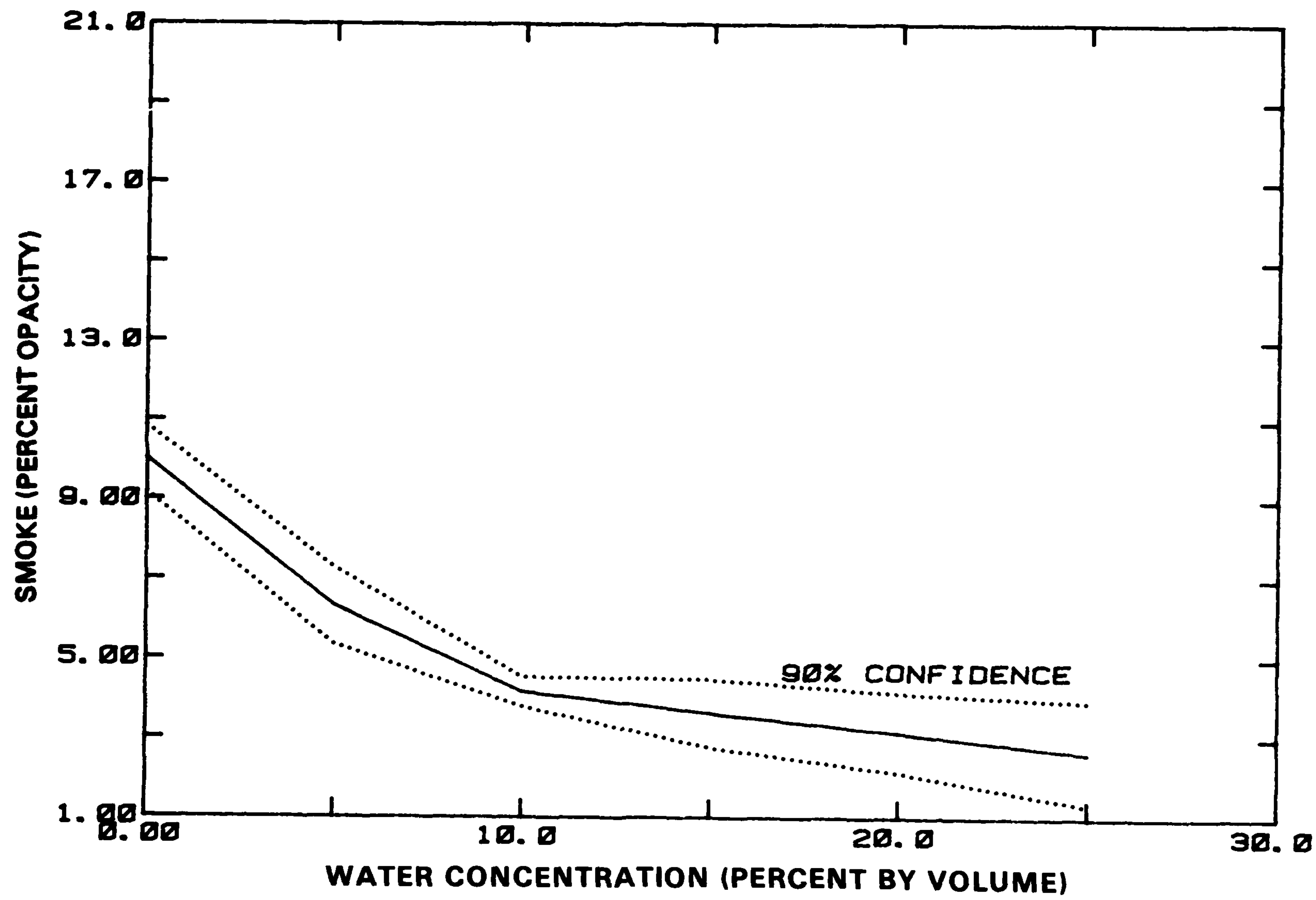


FIGURE 3-10. EXHAUST SMOKE, CUMMINS ENGINE, 1200 RPM

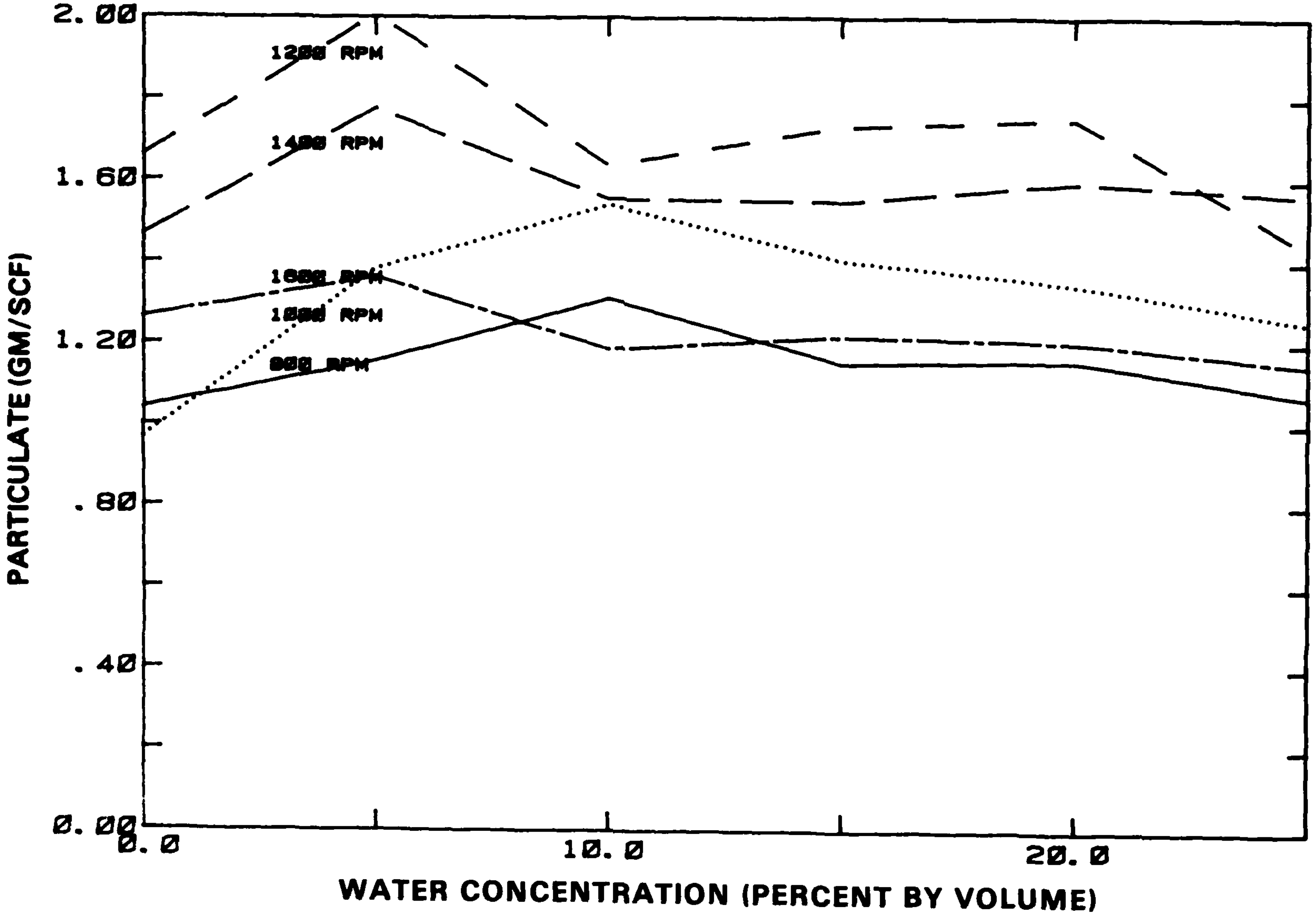


FIGURE 3-11. EXHAUST PARTICULATE EMISSIONS AS FUNCTION OF PERCENT WATER, DETROIT DIESEL ENGINE

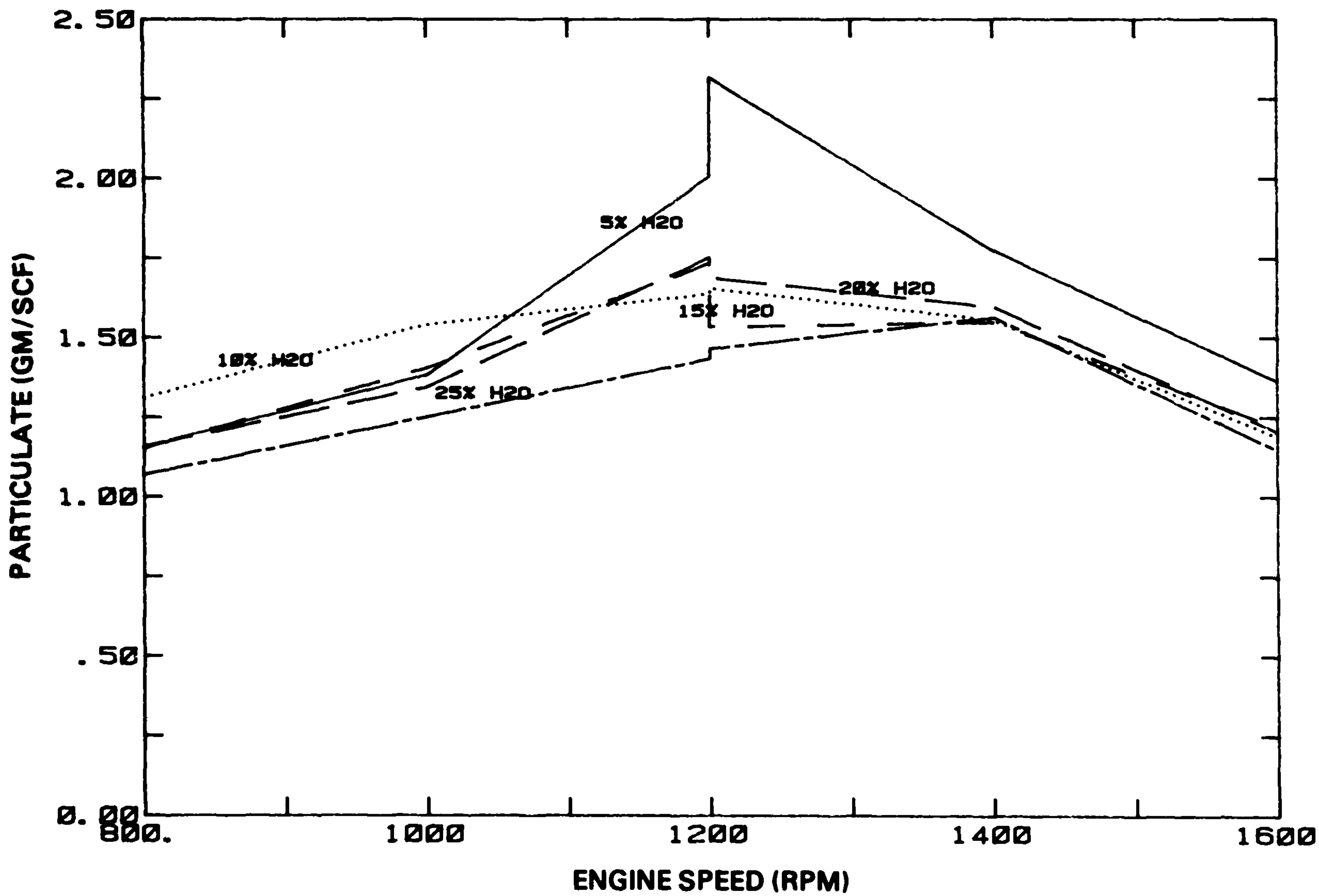


FIGURE 3-12. EXHAUST PARTICULATE EMISSIONS AS FUNCTION OF ENGINE SPEED, DETROIT DIESEL ENGINE

For the Cummins engine, the results of the testing program are summarized in Figure 3-13 for the 1800 rpm test point, and in Figure 3-14 for the 1200 rpm test point. Neither case allows the inference of a reduction in emissions of oxides of nitrogen as phrased in terms of nitric oxide concentrations. In fact, the results at 1800 rpm suggest that water addition did in fact increase the nitric oxide emissions. This result is due in part to a unique characteristic of the cummins fuel injection system. The PT system utilized on the test engine provides for the end of fuel injection at a fixed crank angle location. In other words, the fuel injection event ends at the same point during each engine cycle regardless of the quantity of fuel supplied to the injector. An increase in liquid volume, such as that obtained by the addition of water to the fuel, results in an advance of the point at which injection begins. Thus, the injection event begins earlier in the engine cycle as water is added to the fuel. The effect of injection advance on emissions of oxides of nitrogen is well documented; in general, injection advance tends to increase the emissions of this substance. It is likely, therefore, that the effect of the injection advance offset the tendency toward NO reduction afforded by the presence of water, and the result was the observed constancy or slight increase of nitric oxide levels.

Some specific experiments were performed to assess the degree of injection advance associated with the addition of water to the fuel. Through the use of a strain-gauged component in the injection linkage, a signal was obtained that allowed display of the injection event on an oscilloscope. A series of tests was performed at the 1800 rpm test point; the results are shown in Figure 3-15. The injection event is defined by the point indicated. It may be observed that as the water concentration increases the point at which injection begins tends to advance with respect to the top dead center position. From evaluation of the oscilloscope photographs, it was determined that an injection advance of approximately one degree could be associated with the addition of each five percent water added to the fuel.

Emissions of oxides of nitrogen for the tests of the Detroit Diesel engine are summarized in Figure 3-16; the effect is similar to that observed for the

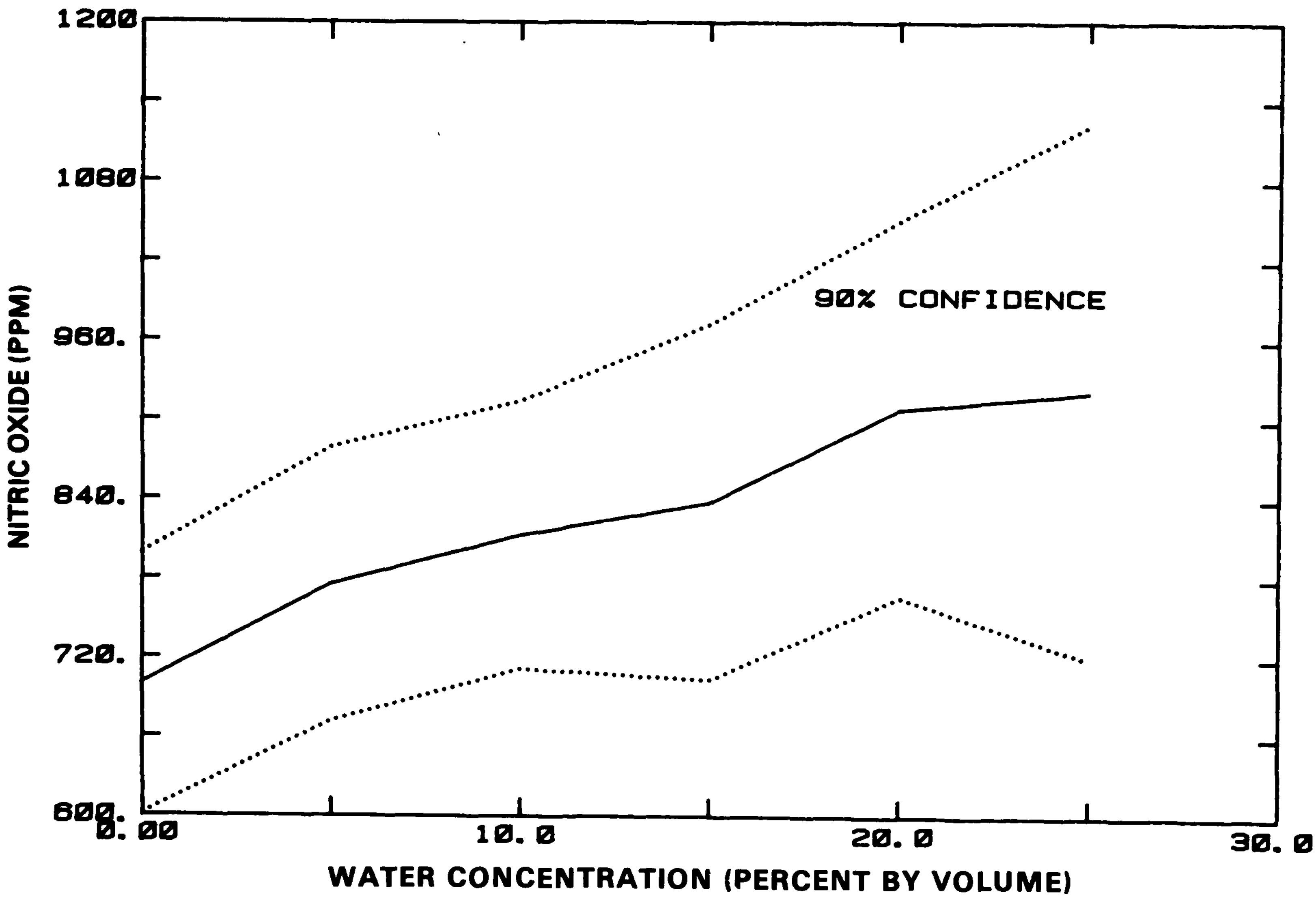


FIGURE 3-13. EMISSIONS OF NITRIC OXIDE, CUMMINS ENGINE, 1800 RPM

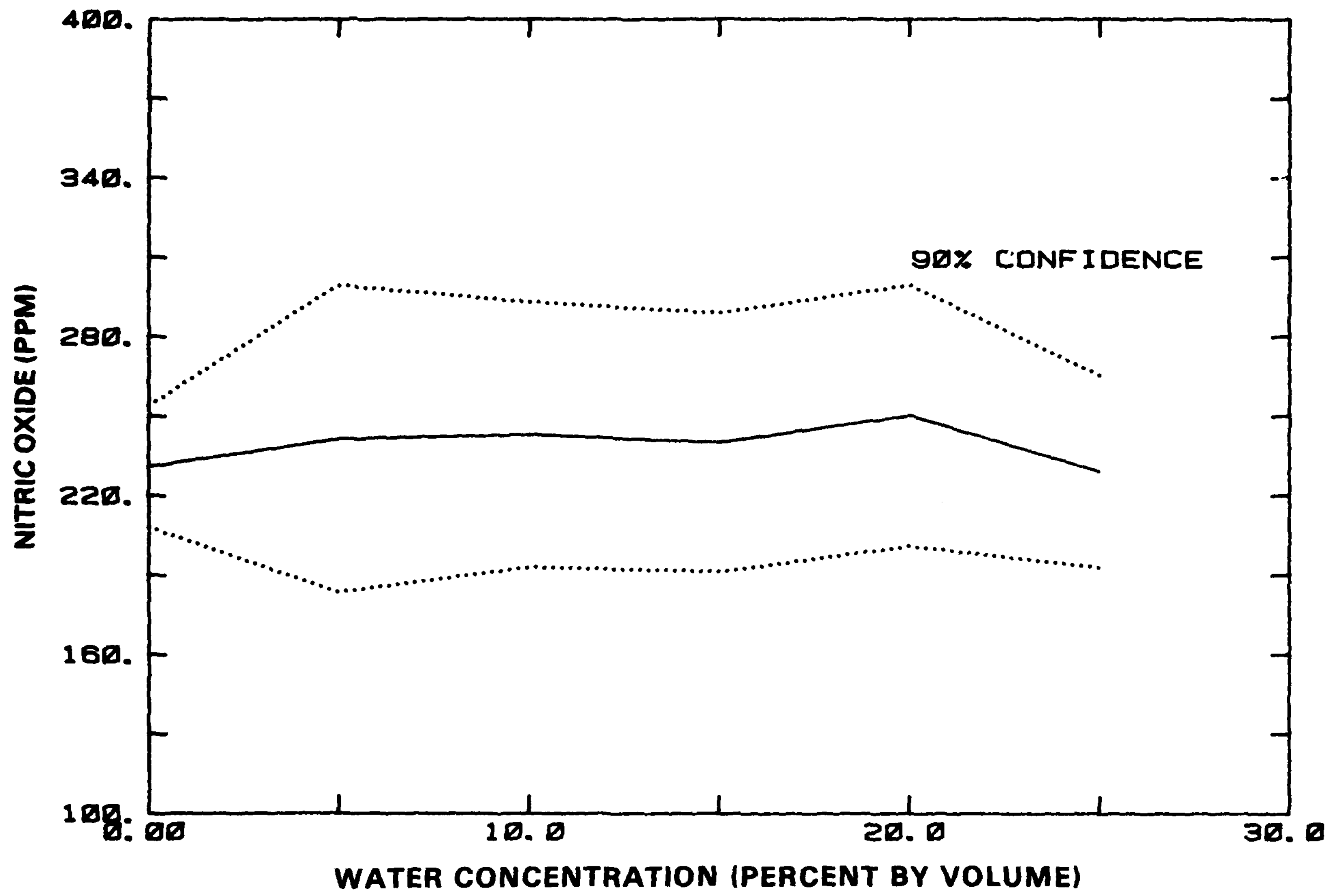
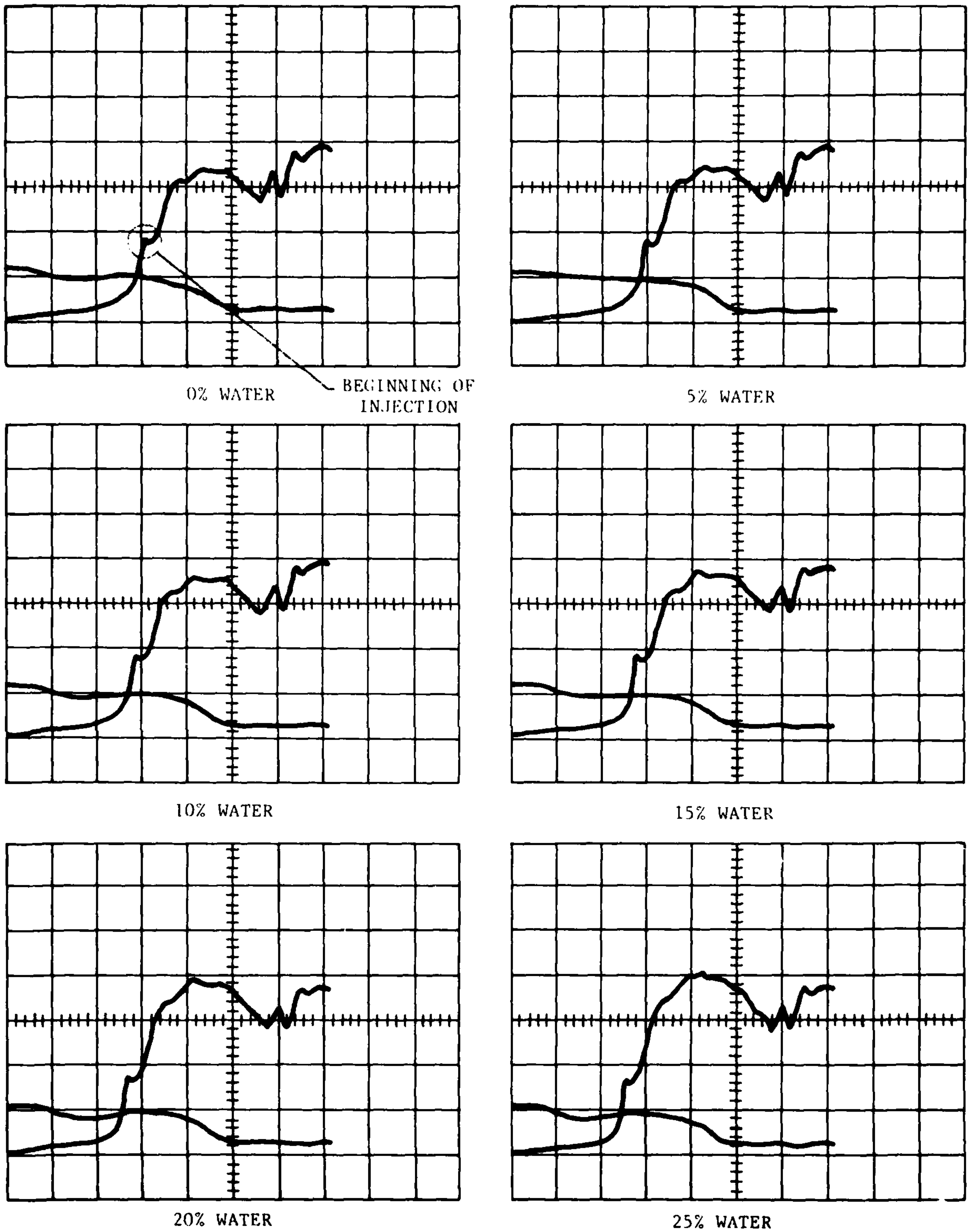


FIGURE 3-14. EMISSIONS OF NITRIC OXIDE, CUMMINS ENGINE, 1200 RPM



Note: Each major vertical division represents ten degrees.

FIGURE 3-15. TIMING OF THE BEGINNING OF FUEL INJECTION, CUMMINS ENGINE

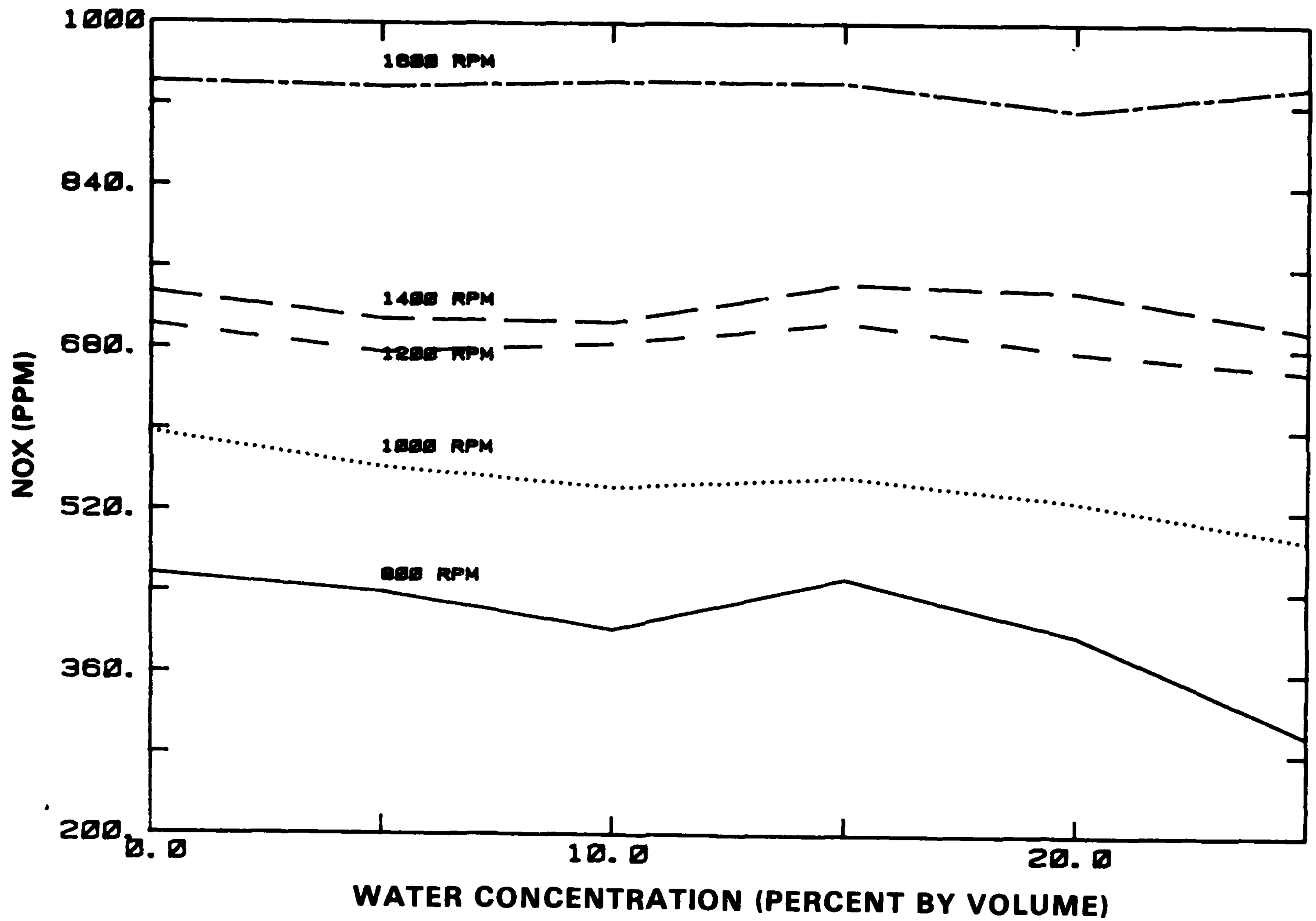


FIGURE 3-16. EMISSIONS OF OXIDES OF NITROGEN, DETROIT DIESEL ENGINE, FIVE SPEEDS

Cummins engine. The emissions increase as the load increases; this result is the usual consequence of increased cycle temperatures. Although some reductions seem to occur at low rpm (800 and 1000) and high water concentrations, in general, the addition of water does not appear to be effective for the reduction of emissions of oxides of nitrogen at any concentration examined during these tests. The explanation used for the lack of influence of water addition on emissions of oxides of nitrogen for the Cummins engine is not applicable in this case; increased liquid quantities do not affect the timing of the beginning of injection for the Detroit Diesel engine.

Two mechanisms may be postulated for the control of emissions of oxides of nitrogen through water addition. First, the water tends to absorb energy from the combustion process, and lower peak cycle temperatures might be attained. In addition, the presence of water tends to increase the ignition delay period; the net effect in this case would be a retarded combustion event. Since both cycle temperature reduction and retarded injection timing have previously been demonstrated as effective control techniques, it would appear that water addition should provide the desired results. However, the data obtained during this program indicate that, if the mechanisms described were operative, they were not sufficient in magnitude to provide effective control. In other words, at the water concentration levels employed and at the engine power levels utilized, the ignition delay increase and the cycle temperature decrease were not sufficient to cause an appreciable decrease in the emissions of oxides of nitrogen.

3.5 UNBURNED HYDROCARBONS

Unburned hydrocarbons are another exhaust contaminant of particular interest in engine exhaust streams. In general, it has been found that the presence of water in the fuel tends to increase the occurrence of unburned hydrocarbons in the exhaust due to a reduction in the cycle temperatures. The hydrocarbon results for the Cummins engine are shown in Figures 3-17 and 3-18 for the test points at 1800 rpm and 1200 rpm. The effect of water addition

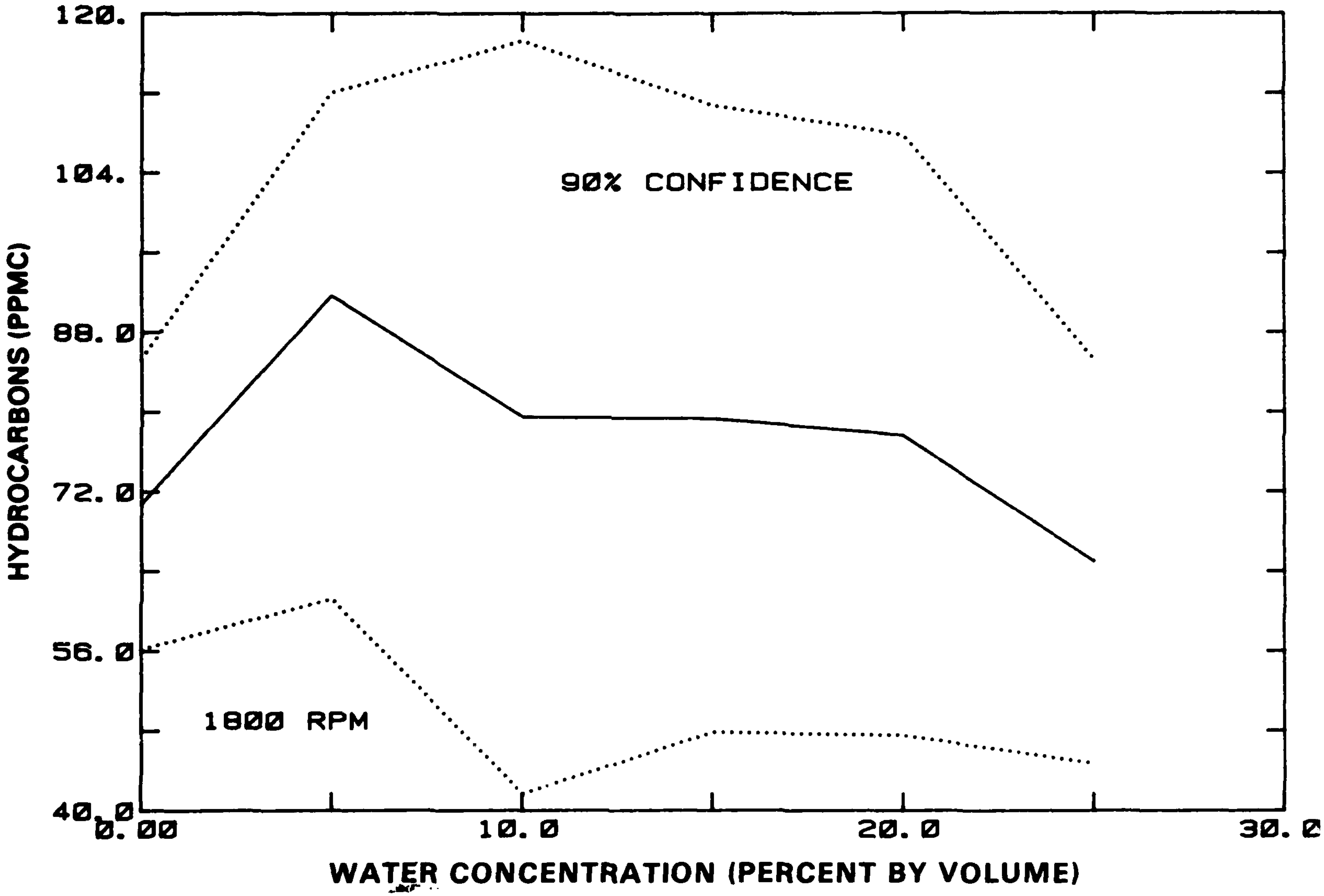


FIGURE 3-17. EMISSIONS OF UNBURNED HYDROCARBONS, CUMMINS ENGINE, 1800 RPM

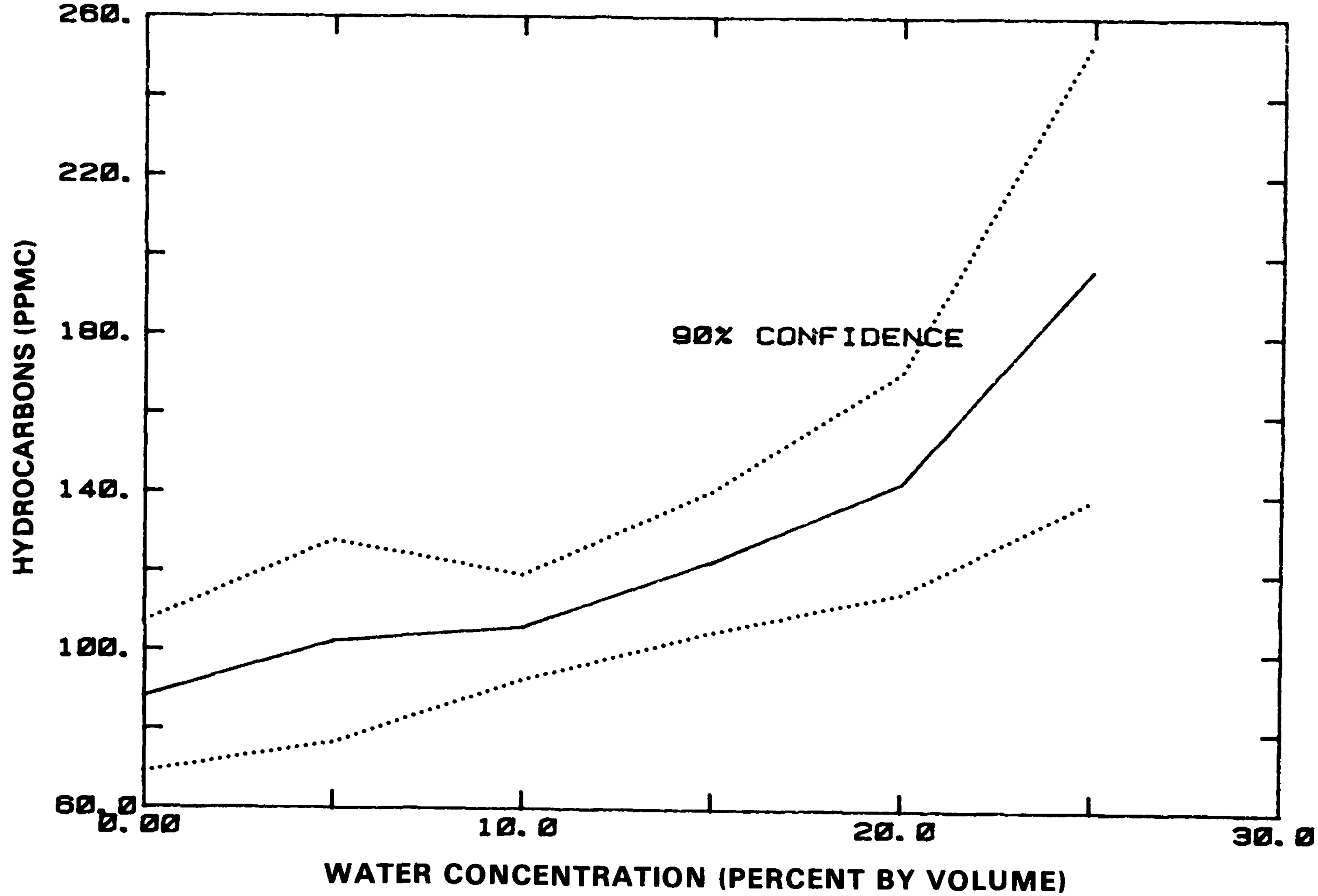


FIGURE 3-18. EMISSIONS OF UNBURNED HYDROCARBONS, CUMMINS ENGINE, 1200 RPM

is largely inconclusive at 1800 rpm; at 1200 rpm an increase in hydrocarbons may be observed. Again, it is likely that the effect of injection advance counteracted the effect of the presence of water to some extent.

For the Detroit Diesel engine, the values of unburned hydrocarbon emissions are shown in Figure 3-19. The magnitudes of the emission levels are higher than those observed for the Cummins engine; this result is not unusual for comparisons between four-stroke cycle and two-stroke cycle engines. The presence of water in the fuel appears to yield an increase in hydrocarbon emissions; the levels associated with five percent water concentration are increased by about thirty percent compared to the baseline values. Water concentrations above five percent, however, had little additional effect on hydrocarbon emissions.

3.6 CARBON MONOXIDE

Carbon monoxide is a contaminant of the same character as unburned hydrocarbons in that both substances occur as a result of incomplete oxidation of the fuel. The situations that cause high hydrocarbon emissions typically cause high carbon monoxide emissions in addition. For the Cummins engine, it may be observed in Figures 3-20 and 3-21 that the character of the carbon monoxide emissions for these tests is similar to that for the emissions of unburned hydrocarbons. The results at 1800 rpm do not indicate a significant change in carbon monoxide emissions, and a moderate increase is apparent for the 1200 rpm test point at the high water concentration.

For the Detroit Diesel engine, the emissions of carbon monoxide are described in Figure 3-22. The results for 1200 rpm suggest a small influence of water concentration on carbon monoxide emissions. At speeds below 1200 rpm, an increasing tendency toward higher emissions may be observed, while an increasing tendency toward emission reduction can be associated with speeds above 1200 rpm. An explanation of this trend may be postulated in terms of the effect of water addition on the ignition delay of the fuel and on the mixing of fuel and air within the cylinder. At the low speeds, the effect of the

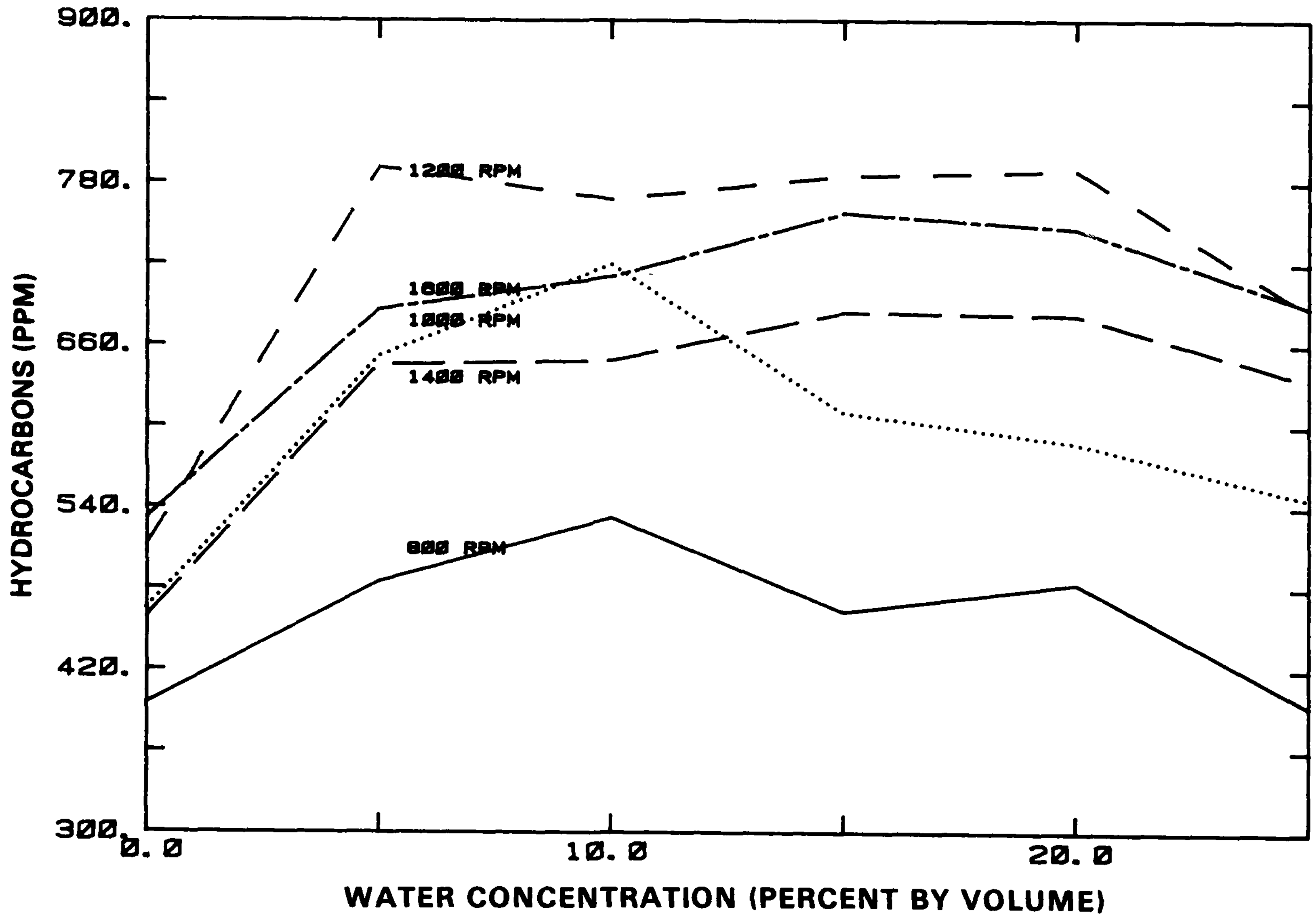


FIGURE 3-19. EMISSIONS OF UNBURNED HYDROCARBONS, DETROIT DIESEL ENGINE, FIVE SPEEDS

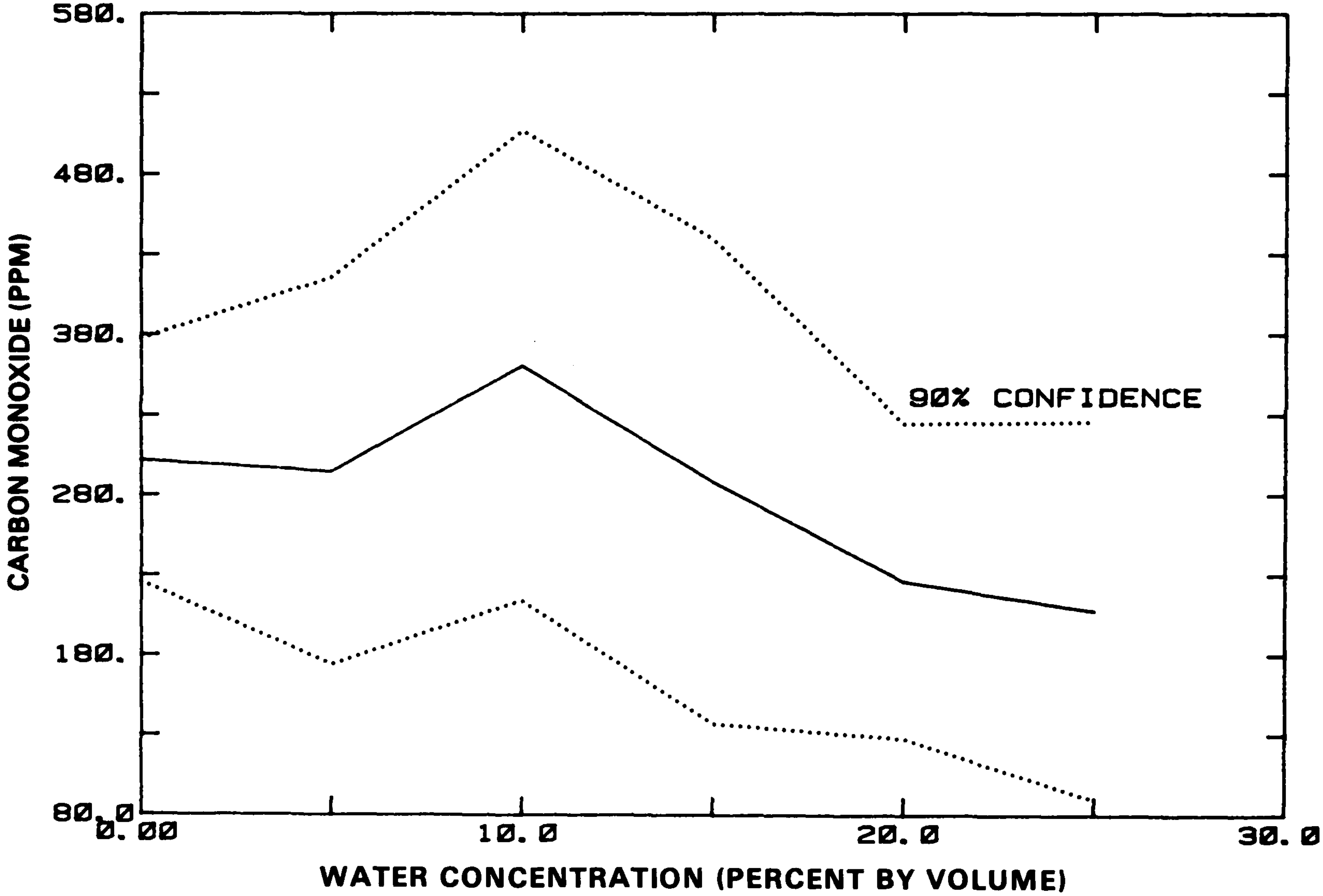


FIGURE 3-20. EMISSIONS OF CARBON MONOXIDE, CUMMINS ENGINE, 1800 RPM

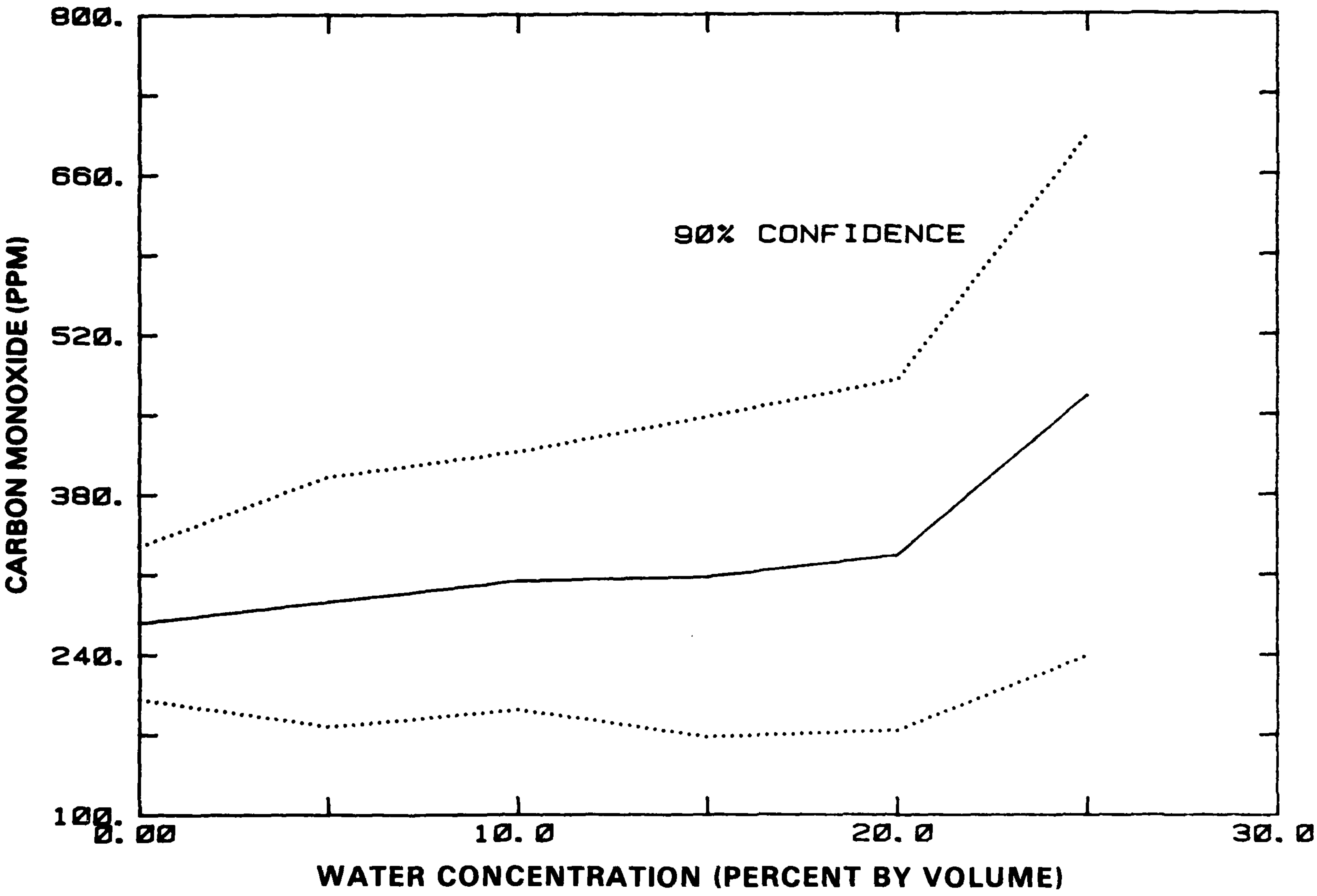


FIGURE 3-21. EMISSIONS OF CARBON MONOXIDE, CUMMINS ENGINE, 1200 RPM

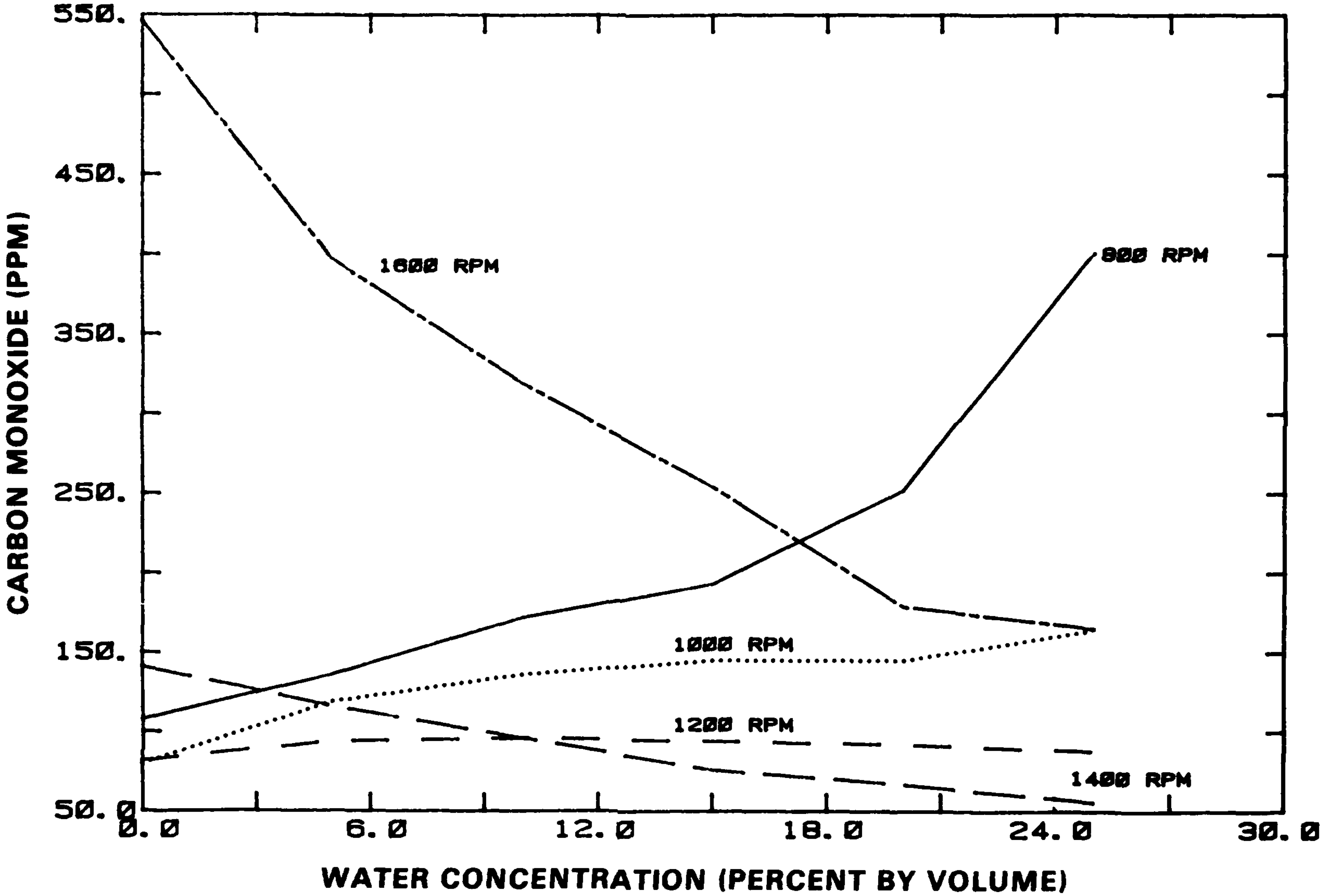


FIGURE 3-22. EMISSIONS OF CARBON MONOXIDE, DETROIT DIESEL ENGINE, FIVE SPEEDS

addition of water on the ignition delay might be sufficient to cause increased emissions of carbon monoxide, although no effect on emissions of hydrocarbons and oxides of nitrogen was discernible.

It may be more appropriate to examine the carbon monoxide emissions from the Detroit Diesel engine in the context of mixing within the engine cylinder. During the 800 rpm tests, the fuel rate was quite small at the prop load condition. The addition of an inert component to the fuel stream would tend to diversify the jet of injected fuel with respect to the interior of the cylinder; the local fuel-air ratio in the vicinity of a fuel droplet would tend to become leaner. Since successful combustion depends upon ignition at points within the chamber and subsequent mixing of burning and unburned materials, it is possible that the addition of water allowed portions of the charge to escape complete inflammation. At the higher fuel rates, this effect of water addition would be reduced, and the effect of water addition on carbon monoxide emissions would be reduced. This argument does not explain the high carbon monoxide levels at the 1600 rpm test point; the baseline carbon monoxide emissions at that point seem uncharacteristically high. Since the fuel-air ratio at this point is well within customary limits for good combustion, poor mixing of air and fuel could be the cause of poor combustion. It is possible that the injection of an increased volume of liquid allowed improved penetration of the fuel injection jet, and increased mixing caused a reduction in carbon monoxide levels to values typical of lower speeds.

3.7 CARBON DIOXIDE AND OXYGEN

The emissions of carbon dioxide and oxygen are recorded in the test data shown in Appendix C. These substances, although not regulated contaminants, are of interest in the generalized context of engine testing. The carbon dioxide measurement is particularly important to carbon balance fuel-air ratio calculations, and results for these estimates have been presented in Figure 2-14.

4. SUMMARY AND CONCLUSIONS

During the testing program described by this document, Cummins and Detroit Diesel engines representative of USCG main propulsion units were operated under loading conditions typical of marine service using water-in-fuel emulsions having various concentrations. Measurements of engine performance and emissions were obtained in an effort to define optimum points for further exploitation of the benefits of emulsified fuels.

The engines were evaluated on a laboratory test bed that included a dynamometer capable of absorbing the maximum engine output. Instrumentation was provided to allow measurement of speed, load, and pertinent temperatures and pressures throughout the installation. Fuel was supplied through a system capable of blending water with diesel fuel in amounts up to 25 percent of the total volume of liquid supplied to the engine; fuel not used by the engine was cooled and recycled through the blending system. No surfactants or stabilizers were employed. A Gaulin "Hydroshear" emulsifier was used to accomplish the mixing of fuel and water, and visual observation of samples obtained from various points suggested that separation of fuel and water did not occur within the fuel system. The fuel consumption measurements were performed using a direct weight method.

Measurements of gaseous exhaust emissions were obtained for both engines using instruments appropriate to the type and level of the individual contaminant substances. In addition, a dilution tunnel was used to measure particulate emissions from the Detroit Diesel engine, and exhaust smoke measurements were obtained for the Cummins engine.

Data from cutter logs were used to define the prop load test points of particular interest for the Cummins engine, and tests were repeated several times for those points in order that a statistical basis for the results could be constructed. For the Detroit Diesel engine, tests were performed at more points along the prop load curve, but the repetition of tests was less extensive.

The fuel consumption tests for the Cummins engine suggested that diesel fuel savings averaging two to three percent could be obtained using emulsion concentrations of fifteen to twenty percent water. No significant fuel saving could be associated with the use of emulsions in the Detroit Diesel engine. Since the laboratory test conditions were generally more favorable than those that would prevail in actual marine use, it is necessary to conclude that the use of water-in-fuel emulsions would not be beneficial to USCG operations.

Measurements of exhaust smoke were performed for the Cummins engine, and particulate emissions were measured for the Detroit Diesel engine. Although dramatic reductions in exhaust plume opacity were observed, the smoke levels for engine operation without water addition were not excessive. Thus, although the data suggest that water-in-fuel emulsions could be used for smoke control, the observation of excessive smoke at any operating point other than full rated load is probably indicative of defective engine components or poor adjustment of engine systems, and smoke control should be effected through correction of those conditions. The addition of water to the fuel did not have a significant effect on the emission of exhaust particulates, although the Detroit Diesel engine was generally insensitive to the presence of water at all test points.

In terms of gaseous exhaust emissions, the expected effects of water addition were not generally observed. The addition of water to the fuel should yield an increase in the emissions of oxides of nitrogen. Although some trends toward these effects could be observed in the test results, no definitive conclusions can be drawn concerning the effect of water addition on emissions.

From a theoretical viewpoint, the addition of water to diesel fuel can result in a mixture which would exhibit unique properties at the onset of combustion. Specifically, it is believed that the vaporization of the water phase causes a "micro-explosion" that is capable of shattering a fuel droplet; the result of this process would be improved mixing of fuel and air and enhanced combustion quality. In addition to improving combustion in a diesel engine, the presence of water in the fuel should lower combustion temperatures, and emissions of unburned hydrocarbons and carbon monoxide should increase. Also, the lower temperature and an increase in the ignition delay period should reduce the emissions of oxides of nitrogen. The micro-explosion phenomenon has been demonstrated for burning of single droplets, and the addition of water to fuel has been suggested for application to a wide range of combustion processes.[2,3,4,5,6]

Several investigators have obtained encouraging test results using water-in-fuel emulsions in diesel engines;[1,6,7,8] others have been less successful in demonstrating benefits associated with the emulsion use.[9,10] The basic engine configuration apparently affects the results; four-stroke cycle engines have generally produced more noticeable effects.

During the present study, all of the observations were macroscopic in nature, and no attempt was made to observe the details of emulsion quality or the micro-explosion event. However, the tests were performed in such a way that the effects of emulsions on engine performance would be revealed.

For the four-stroke cycle (Cummins) engine, the observed reductions in fuel consumption and exhaust stream opacity are indicative of improved mixing between the fuel spray and the air charge within the combustion chamber. The results for unburned hydrocarbons and carbon monoxide were inconclusive, and the emissions of oxides of nitrogen were probably affected by the change in injection timing due to increased fuel quantity. Thus, some evidence can be associated with support of the micro-explosion theory, although the effects were not sufficiently large to be of practical interest.

In the case of the two-stroke cycle (Detroit Diesel) engine, no improvement in fuel consumption or particulate emissions could be observed. Some indication of mixing quality could be inferred from the data on carbon monoxide emissions, but the presumed micro-explosion effects could not be separated from alterations of the fuel spray due to increased injection quantity. In general, the two-stroke cycle engine was quite tolerant of, and insensitive to, the addition of water to the fuel. This result is consistent with the observations of other investigators; for example, some observers have found that water concentrations exceeding 40 percent were necessary to obtain significant changes in engine performance.[11] Such water concentrations lie beyond the range of practical interest for USCG operations.

Both the data obtained during this study and the results reported by other investigators indicate that the effect of water-in-fuel emulsions on engine performance is dependent upon the engine system configuration. Although inferences can be drawn from the body of accumulated information, it is not possible, as yet, to predict the response of an untested engine to the addition of water to the fuel. Additional information must be obtained to define the specific mechanisms which are operative and the effect that these mechanisms exert on the combustion process.

It is possible that further investigation would reveal significant differences between techniques for the production of water-in-fuel emulsions, both in the microstructure of the emulsion product and in the effect on engine operation. Aside from the assurance of a stability sufficient for transit through the fuel system, this study did not address the details of emulsion production. An investigation of the effects of different production techniques, if attempted, should be closely coupled with a study designed to reveal the dominant mechanisms of combustion process control.

5. RECOMMENDATIONS

On the basis of the results obtained during this study, it is recommended that no future effort be directed toward the use of water-in-fuel emulsion in 85 foot and 95 foot WPB class cutters. Although a small fuel consumption benefit was observed for the Cummins engine in a laboratory environment, it is unlikely that a benefit of 2-3 percent could be translated to field use.

The use of water-in-fuel emulsions for smoke control is possible for the Cummins engine, but emulsion use should not be pursued as a control strategy. Excessive smoke at conditions other than engine rated speed and load is indicative of a hardware failure or poor control system adjustment, and correction of the defect is indicated in preference to an auxiliary control strategy.

The data obtained on the Cummins and Detroit Diesel engines do not preclude the successful use of emulsions in other USCG power units. If emulsions are candidates for application to, for example, larger medium-speed diesel engines, then specific tests should be conducted to determine the response of those engines to the presence of water in the fuel system.

Additional basic work will be required in order to formulate general statements concerning the necessary properties of emulsions and the effect of those emulsions on engine performance. While the execution of this basic work is beyond the scope of USCG interests, it is recommended that performance of the basic research efforts be encouraged. Until the general results for emulsion use are understood and documented, tests of specific engine-emulsification system combinations will be necessary for the assessment of practicality.

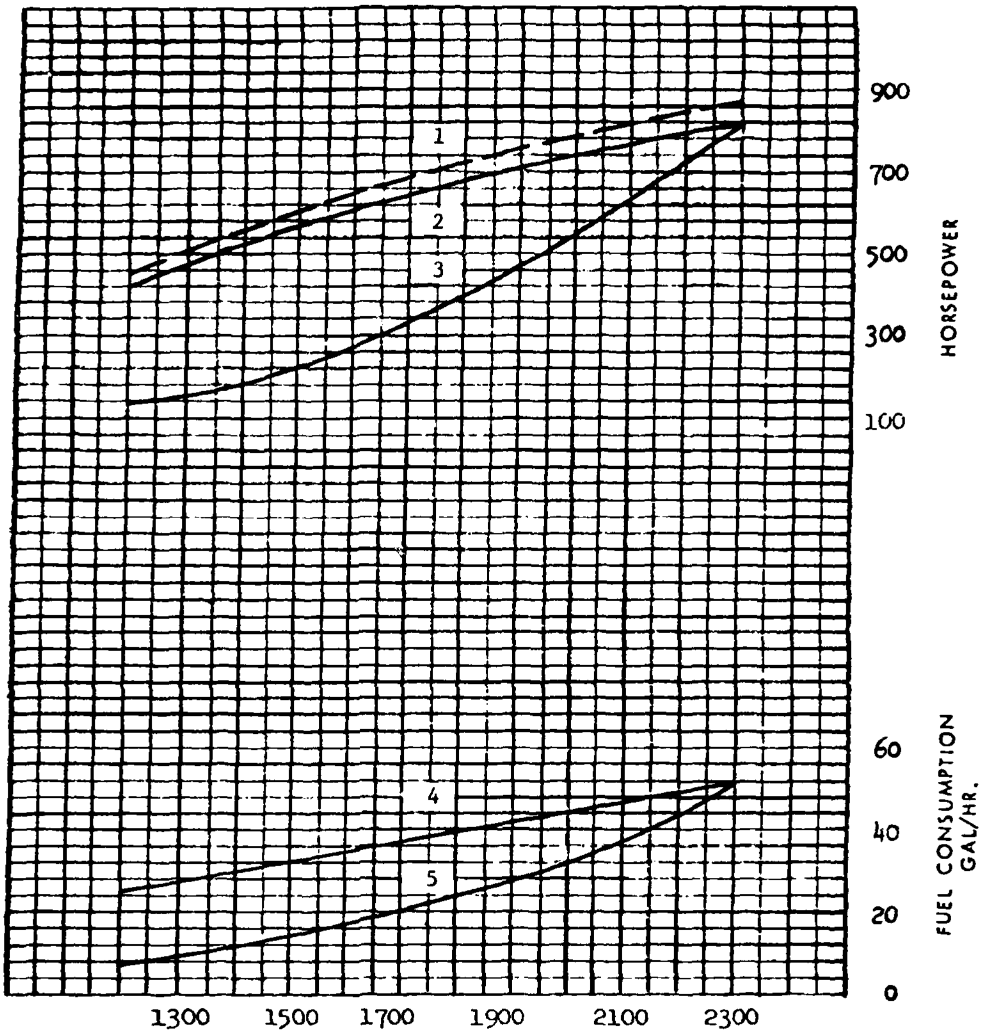
APPENDIX A

FUEL PROPERTIES AND ENGINE DATA

TABLE A-1. FUEL ANALYSIS DATA

PROPERTY	CUMMINS TESTS RUNS 171-282	DETROIT DIESEL TESTS RUNS 1-106	DETROIT DIESEL TESTS RUNS 107-150
Heat of Combustion (BTU/LB)	20,038	20,050	19,400
Hydrogen (% by Weight)	12.83	12.92	13.52
Carbon (% by Weight)	85.75	84.71	84.31
Oxygen (% by Weight)	2.37	1.60	0.96
Nitrogen (% by Weight)	0.68	0.77	0.48
Sulfur (% by Weight	0.18	0.12	0.075
API Gravity at 60°F	35.3	33.9	35.1
Reid Vapor Pressure	1.78	2.60	0.31
Cetane Number (Calc.)	47.5	49.7	50.6
Flash Point (°F)	147	163	162
Viscosity (centistokes)			
50°F	4.91	7.30	5.51
100°F	2.59	3.55	3.14
150°F	1.61	2.18	1.95
210°F	1.07	1.35	1.26
Distillation			
IBP (°F)	360	387	385
10% (°F)	420	463	446
20% (°F)	446	489	473
30% (°F)	464	505	482
40% (°F)	481	520	507
50% (°F)	499	534	522
60% (°F)	514	549	536
70% (°F)	533	568	554
80% (°F)	552	595	579
90% (°F)	581	640	621
95% (°F)	606	682	657
EP (°F)	630	714	700
Recovery (%)	98.5	96.75	98
Residue (%)	1.5	1.25	2
Loss (%)	0.0	2.00	0.0

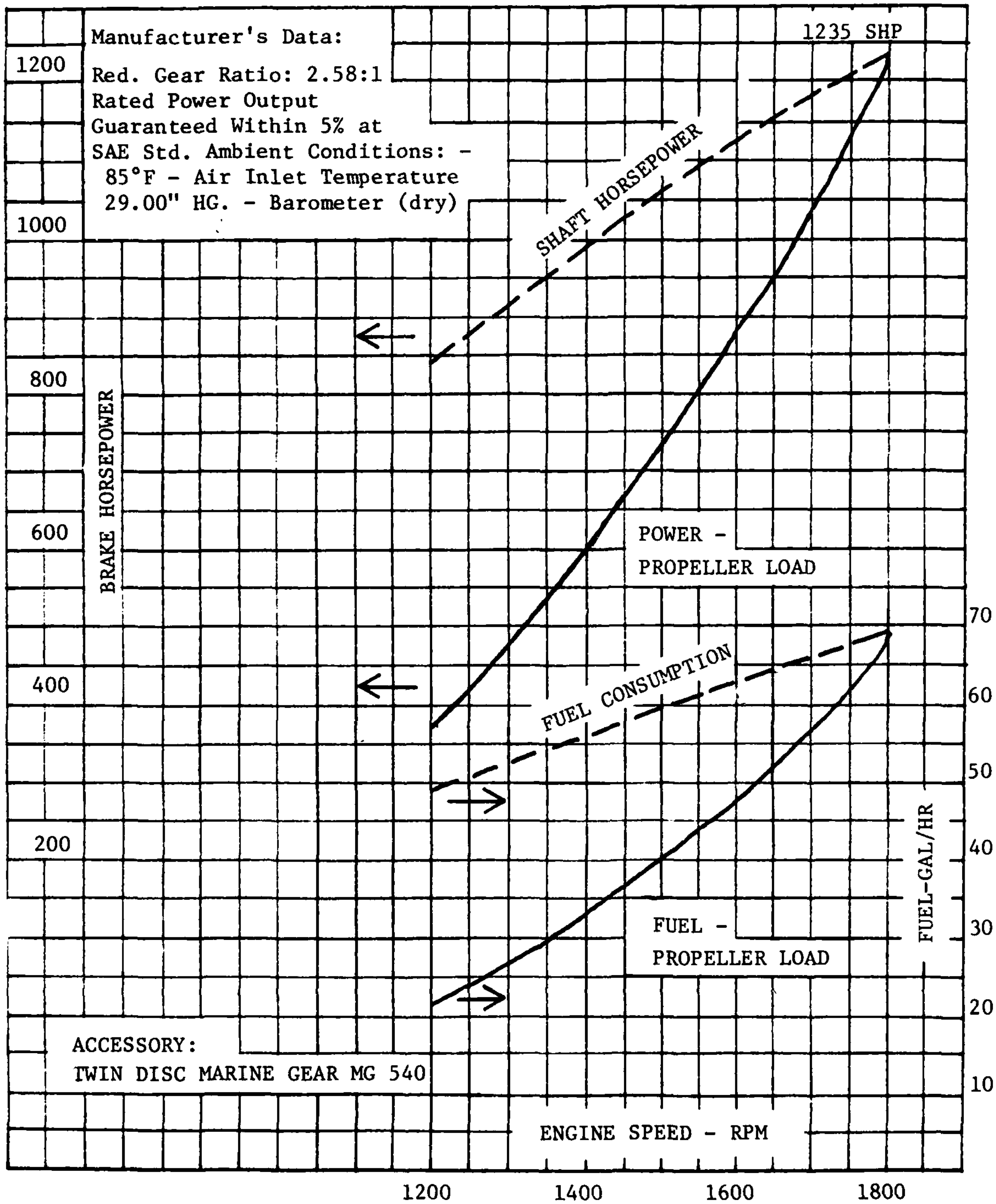
TABLE A-2. MARINE ENGINE PERFORMANCE CURVE



1. GROSS BRAKE HORSEPOWER.
2. NET HORSEPOWER WITH REVERSE REDUCTION GEAR, GENERATOR AND RAW WATER PUMP.
3. HYPOTHETICAL PROPELLER POWER CURVE (3.0 EXPONENT).
4. FUEL CONSUMPTION FOR NET SHAFT HORSEPOWER.
5. FUEL CONSUMPTION FOR HYPOTHETICAL PROPELLER.

The above curves are based on 500 ft. altitude (29.38" HG.) and 85°F intake air temperature; fuel consumption curves are based on fuel weight of 7.0 lb/US gal. Manufacturer's data for Model VT12-900M engine (turbocharged-aftercooled, 12 cylinders, 1710 cu. in. displacement, with 5-1/2 in. bore and 6 in. stroke, military version).

TABLE A-3. ESTIMATED PERFORMANCE SERIES V-149TI MARINE 16V-149TI CREW BOAT, JACKET WATER INTERCOOLER, 150 INJECTORS



APPENDIX B

SAMPLE CALCULATIONS

During each individual test run, engine data were entered on a permanent record sheet. The data items that were recorded are listed in Table B-1 along with the numerical values associated with run number 235 for the Cummins engine; the sample calculations which follow will be based upon the numerical values shown.

The differences between the data items recorded for the Cummins and Detroit Diesel engines were minor. The Detroit Diesel engine was equipped with four turbochargers; therefore, the number of turbocharger-related temperatures and pressures was doubled by comparison with the Cummins engine. Also, air box pressure, rather than fuel rail pressure, was recorded for the Detroit Diesel engine.

Recorded engine test data were entered into a computer program, and several calculation routines were executed. The following discussion describes the details of the calculation procedure, and the numerical values for Cummins run number 235 are presented as an example.

Humidity Calculations

The air supplied to the engine contained some moisture, and the further addition of water to the fuel affected the exhaust moisture. The following equation was used for the calculation of the saturation vapor pressure of water:[12]

$$P_B = \exp\left[B\,\ell n\,T + \sum_{i=0}^{9} F_i\,T^{i-2}\right], \qquad (1)$$

where P_B = saturation vapor pressure, pascals

T = temperature, °K

B = -12.150799

F_0 = -8.49922×10^3

F_1 = -7.4231865×10^3

F_2 = 96.1635147

TABLE B-1. TEST DATA

Date: 24 July 1979 Data Item	Units	Value for Cummins Run 235
Dynamometer Constant	-	3000
Nominal Water Concentration	Percent	20
Barometric Pressure	Inches - Hg	29.03
Wet Bulb Temperature	°F	77
Dry Bulb Temperature	°F	87
Engine Hour Meter	Hours	5222.3
Engine Speed	RPM	1800
Beam Load	Pounds	718
Coolant Inlet Temperature	°F	175
Coolant Outlet Temperature	°F	186
Oil Sump Temperature	°F	219
Fuel Temperature at Emulsifier	°F	112
Diesel Fuel Inlet Temperature	°F	95
Return Fuel Temperature	°F	151
Return Fuel Temperature After Cooler	°F	113
Intake Air Temperature	°F	90
Exhaust Stack Temperature (Left)	°F	762
Exhaust Stack Temperature (Right)	°F	777
Turbine Inlet Temperature (Left)	°F	905
Turbine Inlet Temperature (Right)	°F	917
Compressor Outlet Temperature (Left)	°F	224
Compressor Outlet Temperature (Right)	°F	222
Charge Air Temperature (Left)	°F	189
Charge Air Temperature (Right)	°F	189
Tap Water Inlet Temperature	°F	101
Cell Air Temperature	°F	91
Engine Oil Pressure	psi	76
Fuel Rail Pressure	psi	96

TABLE B-1. TEST DATA, continued

Data Item	Units	Value For Cummins Run 235
Boost Pressure (Right)	psi	9.9
Boost Pressure (Left)	psi	10.0
Turbine Inlet Pressure (Left)	psi	9.0
Turbine Inlet Pressure (Right)	psi	10.0
Inlet Vacuum	In. H_2O	13.9
Exhaust Pressure (Right)	Inches - Hg	0.2
Exhaust Pressure (Left)	Inches - Hg	0.5
Pressure Drop, LFE Filter	In. H2O	5.40
Pressure Drop, Laminar Flow Element	In. H_2O	4.25
Exhaust Temperature, Cylinder 1R	°F	905
Exhaust Temperature, Cylinder 2R	°F	890
Exhaust Temperature, Cylinder 3R	°F	897
Exhaust Temperature, Cylinder 4R	°F	873
Exhaust Temperature, Cylinder 5R	°F	890
Exhaust Temperature, Cylinder 6R	°F	898
Exhaust Temperature, Cylinder 1L	°F	939
Exhaust Temperature, Cylinder 2L	°F	913
Exhaust Temperature, Cylinder 3L	°F	880
Exhaust Temperature, Cylinder 4L	°F	882
Exhaust Temperature, Cylinder 5L	°F	892
Exhaust Temperature, Cylinder 6L	°F	904
Water Flowmeter 1, Glass Float	mm	150+
Water Flowmeter 2, SS Float	mm	115
Water Flowmeter 3, SS Float	mm	0
Fuel Pressure, Tank	psi	20
Pressure, Emulsifier Inlet	psi	100
Pressure, Fuel at Engine	psi	1.6
Water Supply Pressure	psi	65
Emission Concentrations		
Hydrocarbons	ppmc	56
Carbon Monoxide	ppm	148

TABLE B-1. TEST DATA, continued

Data Item	Units	Value For Cummins Run 235
Nitric Oxide	ppm	773
Oxides of Nitrogen	ppm	770
Carbon Dioxide	Percent	7.8
Oxygen	Percent	12.8
Smoke	Percent	3.3
Fuel Flow Measurements	Pounds	5.0
Times: 1	sec	102.3
2	sec	102.6
3	sec	102.4
4	sec	102.7

$$F_3 = 2.4917646 \times 10^{-2}$$
$$F_4 = -1.3160119 \times 10^{-5}$$
$$F_5 = -1.1460454 \times 10^{-8}$$
$$F_6 = 2.1701289 \times 10^{-11}$$
$$F_7 = -3.610258 \times 10^{-15}$$
$$F_8 = 3.8504519 \times 10^{-18}$$
$$F_9 = -1.4317 \times 10^{-21}.$$

Application of this equation to the dry and wet bulb temperatures for run 235 yields the following:

$$P_{WB} = 3168.62 \text{ pascals (at } 298.15°K)$$

$$P_{DB} = 4382.41 \text{ pascals (at } 303.71°K).$$

The vapor pressure at the wet bulb temperature was obtained from "Ferrels equation",

$$P_V = P_{WB} - 0.000660\,(T_{DB} - T_{WB})\,P_{BARO}\left[1 + 0.0015\,(T_{WB} - 273.15)\right], \quad (2)$$

where P_V = vapor pressure, pascals

T_{DB} = dry bulb temperature, °K

T_{WB} = wet bulb temperature, °K

P_{BARO} = barometric pressure, 98307.2 pascals.

Using this relationship, the vapor pressure was found to be

$$P_V = 2797.50 \text{ pascals}.$$

The relative humidity, by definition, was calculated as:

$$RH = \frac{P_V}{P_{DB}} \times 100 = 63.8\%, \quad (3)$$

and the specific humidity was calculated from:

$$H = \frac{(K)(P_V)}{P_{BARO} - P_V}, \tag{4}$$

where H = specific humidity, gm H_2O/gm dry air
K = 0.6220 gm H_2O/gm dry air,

for the test case,

H = 0.0182 gm H_2O/gm dry air
(or pounds moisture/pound dry air).

The volume concentration of the water vapor was calculated on a dry basis as:

$$Y = \frac{(H)(M_{AIR})}{M_{H_2O}} = 0.0293, \tag{5}$$

where Y = water vapor volume concentration
M_{AIR} = molecular weight of air = 28.9645
M_{H_2O} = molecular weight of water = 18.01534/

Water Flow Rate Calculations

Although a nominal water concentration was associated with each test run, the actual flow to the engine fuel system was measured using variable area flowmeters. The flowmeters were calibrated with water prior to the initiation of testing, and a fifth order curve was fitted to the calibration data. Two flowmeters were utilized, and one of the two units contained two floats; thus three calibrated flow ranges were available. The matrix of flowmeter constants is shown in Table B-2. The water flow determination was based upon the flow range most applicable to the particular test run; the procedure was

$$WFR = W_1 + W_2(X) + W_3(X^2) + W_4(X^3) + W_5(X^4) + W_6(X^5), \tag{6}$$

where WFR = water flow rate, cc/min

TABLE B-2. WATER FLOWMETER CURVE COEFFICIENTS

	Meter 1 Glass Float	Meter 1 Stainless Steel Float	Meter 2 Stainless Steel Float
W_1	0.1124503×10^{2}	-0.3398302×10^{1}	0.1701297×10^{1}
W_2	-0.1180202×10^{1}	0.8969192	0.7123502
W_3	0.6830435×10^{-1}	0.7994353×10^{-1}	0.1005951
W_4	$-0.7587800 \times 10^{-3}$	$-0.1017442 \times 10^{-2}$	$-0.1434834 \times 10^{-2}$
W_5	0.3808533×10^{-5}	0.5968658×10^{-5}	0.8912745×10^{-5}
W_6	$-0.6943106 \times 10^{-8}$	$-0.1340098 \times 10^{-7}$	$-0.2025536 \times 10^{-7}$

W = calibration coefficient, Table B-2

X = flowmeter scale reading, mm.

The calculated water flow rate was utilized in subsequent calculations for the measured water concentration and the corrected exhaust humidity. For the example situation (run 235), the water flow rate was:

$$WFR = 384 \text{ cc/min} .$$

Engine Performance Calculations

The observed brake horsepower was calculated from the engine speed and load:

$$BHP = \frac{(N)(L)}{K} , \tag{7}$$

where BHP = brake horsepower

N = engine speed, rpm

L = dynamometer beam load, pounds

K = dynamometer constant

= 3000 for Cummins tests

= 2000 for DDAD runs 1 - 106

= 3000 for DDAD runs 107 - 150.

For the case of Cummins run 235,

$$BHP = \frac{(1800)(718)}{3000} = 431 .$$

The observed torque was obtained from

$$T = \frac{(5252)(L)}{K} = 1257 \text{ lb. ft.} , \tag{8}$$

where T = torque, lb. ft.

L = beam load, lb.

K = dynamometer constant.

Correction factors for the observed engine performance were developed on the basis of atmospheric conditions.[13] The dry barometric pressure was calculated from

$$P_{B,\ DRY} = P_{BARO} - \frac{P_V}{K_P} = 28.20 \text{ in. Hg}, \tag{9}$$

where $P_{B,\ DRY}$ = dry barometric pressure, in. Hg
K_P = 3386.4 pascal/in. Hg.

the value of the correction factor was then obtained

$$C_D = \left(\frac{29.00}{P_{B,\ DRY}}\right)\left(\frac{T_{test}}{545}\right)^{0.7}, \tag{10}$$

where C_D = correction factor
t_{test} = intake air absolute temperature, °R.

For the specific test case,

$$C_D = \left(\frac{29.00}{28.20}\right)\left(\frac{90 + 460}{545}\right)^{0.7} = 1.035,$$

therefore, the corrected horsepower was

$$CBHP = (431)(1.035) = 446.$$

The mean effective pressure is a useful parameter that describes engine output per unit area of piston surface. In the calculation routine, values were obtained from the relationship

$$bmep = \frac{K_m\ (CBHP)}{(D)(N)} = 115, \tag{11}$$

where bmep = brake mean effective pressure, psi

K_m = constant, 792,000 for 4-stroke cycle

396,000 for 2-stroke cycle

D = engine displacement, cubic inches

= 1710 for Cummins engine

= 1788 for Detroit Diesel engine

N = engine speed, rpm.

Air Flow Calculations

During the Cummins engine tests, the air flow to the engine was measured using a Meriam Laminar Flow Element. During test runs, the pressure drop across the element, the pressure drop across the filter, and the temperature of the incoming air were recorded. The volume flow rate was obtained from a curve fitted to the flow element calibration curve by means of the following relationship:

$$CFM = AC + BC\ (dp) + CC\ (dp)^2 + DC\ (dp)^3\ , \tag{12}$$

where CFM = volume flow, cubic feet per minute

dp = pressure drop across element, inches of water

AC = 0.0

BC = 298.825

CC = 5.88898

DC = 0.19913.

For the example calculation, it may be observed that

$$CFM = 1179\ .$$

Two correction factors were used to adjust the volume flow rate to the calibration basis of standard cubic feet per minute. The pressure correction was

$$PCF = \frac{P_{BARO} - (dp\ filter)(0.07355)}{29.92} = 0.957\ , \tag{13}$$

where PCF = pressure correction factor

dp filter = pressure drop across filter, inches of water.

The correction for temperature was obtained from a curve fitted to data supplied with the instrument (Table B-3).[14]

$$TCF = X_1 + X_2(T_i) + X_3(T_i)^2 + X_4(T_i)^3 = 0.937, \quad (14)$$

where TCF = temperature correction factor

T_i = inlet air temperature, °F

X_1 = 1.28345

X_2 = -0.0048289

X_3 = 1.227782×10^{-5}

X_4 = -1.618912×10^{-8}.

The air mass flow rate was then established in terms of air density at the calibration condition (70°F) as:

$$AMF = (CFM)(PCF)(TCF)(\rho s) = 79.2, \quad (15)$$

where AMF = air mass flow, pounds per minute

ρs = density of air at 70°F and 29.92 inches of mercury, pounds per cubic foot.

The air flow rate was adjusted using the previously calculated moisture concentration:

$$DAMF = AMF\ (1.0 - H), \quad (16)$$

where DAMF = mass flow rate of dry air, pounds per minute

H = moisture, pounds water per pound dry air.

For the example calculation,

$$DAMF = 79.2\ (1.0 - 0.0182) = 77.8.$$

TABLE B-3. AIR TEMPERATURE CORRECTION FACTORS

AIR TEMPERATURE CORRECTION FACTORS FOR SCFM
AIR BASE TEMPERATURE 70°F, VISCOSITY 181.87 MICROPOISE
REFERENCE NBS CIRCULAR 564

$$\text{CORRECTION FACTOR} = \frac{529.67}{459.67 + {}^\circ F} \times \frac{181.87}{\mu g^*}$$

μg^* Viscosity of Air at flowing temperature

TEMP °F	+0	+1	+2	+3	+4	+5	+6	+7	+8	+9
50	1.0707	1.0670	1.0633	1.0596	1.0559	1.0523	1.0487	1.0451	1.0415	1.0379
60	1.0344	1.0303	1.0273	1.0238	1.0204	1.0169	1.0135	1.0101	1.0067	[illegible]
70	1.0000	.9966	.9933	.9900	.9867	.9834	.9802	.9770	.9737	.9705
80	.9674	.9642	.9611	.9579	.9548	.9517	.9486	.9456	.9425	[illegible]
90	.9365	.9335	.9305	.9275	.9246	.9216	.9187	.9158	.9129	.9100
100	.9072	.9043	.9015	.8987	.8959	.8931	.8903	.8875	.8848	.8820
110	.8793	.8766	.8739	.8712	.8686	.8659	.8633	.8606	.8580	.8554
120	.8528	.8503	.8477	.8452	.8426	.8401	.8376	.8351	.8326	.8301
130	.8276	.8252	.8227	.8203	.8179	.8155	.8131	.8107	.8083	.8060
140	.8036	.8013	.7990	.7966	.7943	.7920	.7898	.7875	.7852	[illegible]
150	.7807	.7785	.7763	.7741	.7719	.7697	.7675	.7653	.7632	[illegible]

Fuel Flow Calculations

During each test run, several measurements of the mass flow rate of diesel fuel were performed. The determinations were made by observing the time required for consumption of a known mass of fuel from a container on a scale; the fuel masses were varied to permit time measurements on the order of two minutes. Each fuel mass flow rate was calculated, and an average was obtained. For the case of Cummins run 235, the following data apply:

Observation	1	2	3	4
Fuel mass, pounds	5.0	5.0	5.0	5.0
Time, seconds	102.3	102.6	102.4	102.7
Fuel rate, pounds per hour	175.95	175.44	175.78	175.27

Average Fuel Rate = F = 175.61 pounds per hour.

The brake specific fuel consumption was calculated from the average fuel rate and the corrected brake horsepower:

$$\text{BSFC} = \frac{F}{\text{CBHP}} = 0.3939 \text{ pounds fuel per brake horsepower hour.} \tag{17}$$

As a consequence of the fuel and air flow determinations, the observed fuel-air ratio was calculated:

$$\left(\frac{F}{A}\right)_{\text{MEAS}} = \frac{F}{(\text{DAMF})(60)} = 0.0376. \tag{18}$$

In order to obtain the fuel volume flow rate, a hydrometer measurement of the API gravity of the fuel was obtained and corrected to 60°F through the use of ASTM IP Table 5.[15] The value at 60°F was then used in the context of ASTM IP Table 3[15] to determine the specific gravity of the fuel; for the test case, the specific garvity of the fuel at 60°F compared to water at 60°F was:

$$SG_{60/60} = 0.8483,$$

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MULTICYLINDER DIESEL ENGINE TESTS WITH UNSTABILIZED WATER-IN-FU--ETC(U)

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the fuel density was then calculated as

$$\rho_{fuel} = (\rho_{water})(SG_{60/60})\left(\frac{ft^3}{1728\ in^3}\right)\left(\frac{231\ in^3}{gallon}\right) = 7.074\ , \tag{19}$$

where ρ_{fuel} = fuel density, pounds per gallon

ρ_{water} = density of water at 60°F

= 62.38 pounds per cubic foot

A temperature correction for the difference between the 60°F standard and the observed fuel temperature was established from ASTM IP Table 6 [15] and using the 60°F value of the API gravity. Values of the volume reduction factor were selected from the table for the temperature range 60°F - 120°F, and a curve was fitted to the data. The temperature correction was:

$$TF = Z_1 + Z_2(T_f) + Z_3(T_f)^2 + Z_4(T_f)^3\ , \tag{20}$$

where TF = temperature correction factor for fuel volume

T_f = fuel temperature, °F

Z_1 = 0.102678×10

Z_2 = -0.446429×10^{-3}

Z_3 = -0.14715×10^{-12}

Z_4 = 0.10462×10^{-14} ,

for the example case of run 235,

$$TF = 0.9844\ .$$

The fuel density at the test condition was, therefore,

$$\rho_{ft} = (7.074)(TF) = 6.963 \text{ pounds per gallon}\ ,$$

and the fuel volume flow rate was

$$V_F = \frac{(F)(A)}{(\rho_{Ft})(B)} = 1591, \quad (21)$$

where V_F = fuel volume flow rate, cc per minute

A = conversion factor, 3785 cc per gallon

B = conversion factor, 60 minutes per hour.

As a result of the fuel volume flow determination, the water concentration in the fuel mixture was calculated:

$$W = \frac{WFR}{WFR + V_F} \times 100 = 19.4\% , \quad (22)$$

where W = water concentration, percent

WFR = water flow rate, cc per minute

V_F = fuel flow rate, cc per minute.

In order to facilitate subsequent calculations, the water content of the exhaust was modified to include the water introduced with the fuel along with the water entrained in the inlet air. Assuming a density of one gram per cubic centimeter for water,

$$WF = \frac{WFR}{453.6} = 0.8466, \quad (23)$$

where WF = water flow rate, pounds per minute

WFR = water flow rate, cc per minute,

then,

$$PR = \frac{WF}{DAMF} = 0.0109, \quad (24)$$

where PR = moisture added with fuel, pounds water per pound dry air

and

$$H' = H + PR = 0.0217 , \tag{25}$$

where H' = specific humidity of exhaust, pounds water per pound dry air.

The corrected volume concentration was

$$Y' = \frac{(H')(M_{AIR})}{M_{H2O}} = 0.0349 . \tag{26}$$

Exhaust Calculations

From the fuel analysis data shown in Appendix A, the hydrogen/carbon ratio of the fuel was calculated as follows:

$$HCR = \left(\frac{HD}{CA}\right)\left(\frac{M_C}{M_H}\right) = 1.78 , \tag{27}$$

where HCR = fuel hydrogen/carbon ratio
HD = 12.83 = hydrogen content, percent by weight
CA = 85.75 = carbon content, percent by weight
M_C = 12.001 = molecular weight of carbon
M_H = 1.008 = molecular weight of hydrogen.

The concentrations of various exhaust constituents were measured using instruments appropriate to the type of gas and the level present in the exhaust stream. Each relevant range of each instrument was calibrated monthly using at least four gas mixtures within the range, and both zero and span gases were applied to each relevant range before and after testing on each test day. During each test run, scale readings from the instruments were compared to curves developed from the monthly calibrations, and concentrations were reported in parts per million (ppm) or percent. Three gas species, unburned hydrocarbons, carbon monoxide, and carbon dioxide, were of particular importance for the calculation of an air-fuel ratio. The hydrocarbon measurements were made on a wet basis, and the concentrations were corrected to a dry basis during the calculation procedure.

The air-fuel ratio was calculated from exhaust constituent levels using relationships described in the Federal Register.[12] The initial calculation was for the stoichiometric fuel-air ratio:

$$\left(\frac{F}{A}\right)_{STOICH} = \frac{M_C + (HCR)\ M_H}{138.18\left(1 + \frac{HCR}{4}\right)} = 0.0691\,. \qquad (28)$$

The equivalence ratio was then calculated from

$$\phi = \frac{\left(\frac{F}{A}\right)_{MEAS}}{\left(\frac{F}{A}\right)_{STOICH}} = 0.544\,. \qquad (29)$$

For convenience, the following ratios were calculated:

$$R_1 = \frac{HCC}{10^6}$$

$$R_2 = \frac{CO}{10^6}$$

$$R_3 = \frac{CO_2}{10^2}\ ,$$

where HCC = measured hydrocarbon concentration, parts per million carbon

CO = measured carbon monoxide concentration, parts per million

CO_2 = measured carbon dioxide concentration, percent.

The wet-to-dry correction factor was then obtained from:

$$K_w = \frac{1}{1 + \left[\dfrac{HCR(R_2 + R_3) + \frac{2Y'}{\phi}(R_1 + R_2 + R_3)(1 + \frac{HCR}{4})}{2 \quad 1 + \frac{R_2}{(R_3)(K)}}\right]} = 0.929\,, \qquad (30)$$

where K_w = wet-to-dry correction factor

K = water-gas equilibrium constant = 3.5 .

then the hydrocarbon concentration that would exist in a dry stream was calculated:

$$HCD = \frac{HCC}{K_w} = 60 , \tag{31}$$

and

$$R_4 = \frac{HCD}{10^6} . \tag{32}$$

It was convenient to define the parameter

$$\bar{X} = R_2 + R_3 + R_4 , \tag{33}$$

for use in subsequent calculations

The exhaust fuel-air ratio was obtained from the relationship

$$\left(\frac{F}{A}\right)_{calc} = \frac{4.77\left(1 + \frac{HCR}{4}\right)\left(\frac{F}{A}\right)_{STOICH}}{\frac{1}{\bar{X}} - \left(\frac{R_2}{2\bar{X}}\right) - \left(\frac{R_4}{\bar{X}}\right) + \left(\frac{HCR}{4}\right)\left(1 - \frac{R_4}{\bar{X}}\right) - \frac{(0.75)(HCR)}{\left(\frac{K}{\left(\frac{R_2}{\bar{X}}\right)}\right) + \left(\frac{1 - K}{1 - \frac{R_4}{\bar{X}}}\right)}} . \tag{34}$$

For the data representing Cummins run 235, the calculated fuel-air ratio was

$$\left(\frac{F}{A}\right)_{calc} = 0.0358 .$$

The difference between the calculated and measured values of the fuel-air ratio was obtained from

$$D = \frac{\left(\frac{F}{A}\right)_{calc} - \left(\frac{F}{A}\right)_{meas}}{\left(\frac{F}{A}\right)_{meas}} (100) = -4.9, \tag{35}$$

where D = percentage difference between measured and calculated fuel-air ratios.

According to reference (12), the absolute value of D should be less than 10 for most engine operating conditions.

The measured concentrations of nitric oxide were corrected for humidity using relationships described in reference (12). The calculation of the correction factor depends upon inlet air temperature, exhaust stream humidity, and the measured dry fuel-air ratio:

$$K_{NO_x} = \frac{1}{1 + A(G - 75) + B(T - 85)} = 1.19, \tag{36}$$

where $A = 0.044 \left(\frac{F}{A}\right)_{meas} - 0.0038$

$B = -0.116\left(\frac{F}{A}\right)_{meas} + 0.0053$

G = humidity in grains per pound dry air

= (7000)(H')

T = inlet air temperature, °F ,

then

$$DNO = (NO)(K_{NO_x}), \tag{37}$$

where DNO = corrected nitric oxide concentration

NO = measured dry nitric oxide concentration.

The above correction is based upon the use of a water-ice bath for condensation of the water vapor present in the exhaust stream. The specific instrument used for this program employed a methanol-dry ice bath for this purpose; the bath temperature was about -150°F. Thus, an additional correction for moisture removal was used:

$$DKNO = \frac{DNO}{1.00678} . \qquad (38)$$

The dry values of the exhaust constituent concentrations were used for the calculation of mass emissions. Again, several ratios were defined for convenience:

$$R_5 = \frac{HCD}{10^4}$$

$$R_6 = \frac{CO}{10^4}$$

$$R_7 = R_6 + CO_2 + R_5$$

$$R_8 = \frac{DKNO}{10^4} .$$

The mass emissions, in grams per hour, were obtained from the following relationships:

$$W_{HC} = \frac{(R_5)(W_F)}{R_7} = 61 \qquad (39)$$

$$W_{CO} = \frac{(M_{CO})(R_6)(W_F)}{(M_C + (HCR)(M_H))(R_7)} = 306 \qquad (40)$$

$$W_{NO_x} = \frac{(M_{NO_2})(R_8)(W_F)}{(M_C + (HCR)(M_H))(R_7)} = 2940 , \qquad (41)$$

where W_{HC}, W_{CO}, W_{NO_x} = mass emissions of exhaust constituent, grams per hour

W_F = mass flow rate of diesel fuel, grams per hour = (453.6)(F)

M_{CO} = molecular weight of CO = 28.0

M_{NO_x} = molecular weight of NO_2 = 46.0
M_C = molecular weight of carbon
M_H = molecular weight of hydrogen.

The specific emissions were calculated on the basis of the corrected brake horsepower:

$$S_{HC} = \frac{W_{HC}}{CBHP} = 0.14 \tag{42}$$

$$S_{CO} = \frac{W_{CO}}{CBHP} + 0.69 \tag{43}$$

$$S_{NO_x} = \frac{W_{NO_x}}{CBHP} = 6.59 \ , \tag{44}$$

where S_{HC}, S_{CO}, S_{NO_x} = specific emissions, grams per brake horsepower hour.

Statistical Calculations

During the Cummins engine tests, statistical procedures were used to evaluate the confidence in certain measured results and to assess the probable effect of the addition of water to the fuel. The performance of the statistical tests required that test procedures be repeated several times under the same conditions in order to provide suitable samples.

As an example of the statistical techniques, two sets of test data will be considered. Table B-4 contains a list of all of the diesel fuel consumption rates observed for the Cummins engine with no water addition and with 20 percent water addition. Sample 1, for no water addition, was regarded as a sample of the entire population of test runs that could be performed at the specified engine setting without water addition. Similarly, Sample 2 was considered to be representative of all of the test runs that might be conducted at the specified engine condition with 20 percent water addition.

The mean of each sample was calculated according to the relationship

$$\bar{X} = \frac{1}{\eta} \sum_{i=1}^{\eta} X \ , \tag{45}$$

TABLE B-4. POPULATION SAMPLES

Diesel Fuel Flow Rates at 1200 RPM
Cummins Engine Tests

Sample 1

0% Water

Run	Fuel Rate
178	54.72
188	55.30
194	54.43
224	54.84
230	55.04
238	54.94
244	55.58
252	56.01
258	55.94
Mean	55.20
S	0.5482
90% band	55.20 ± 0.340

Sample 2

20% Water

Run	Fuel Rate
182	53.71
192	53.04
228	53.92
242	53.80
256	54.77
Mean	53.85
S	0.6184
90% band	53.85 ± 0.5896

where $\bar{X}$ = sample mean

η = number of items in sample

X = value of each fuel rate in the sample.

The calculated mean value for each sample is shown in Table B-4.

The standard deviation for each sample was calculated according to:

$$S = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{\eta}}{\eta - 1}} , \qquad (46)$$

where the individual terms are defined above. The standard deviation for each sample is also shown in Table B-4.

One statistical test was applied to each sample as an individual entity. The Student's t-distribution was used to attach a confidence band to each sample mean. Values of the t-distribution are shown in Table B-5.[16] For a desired confidence level, say 90 percent, it can be argued that the true population mean lies within the band defined by

$$\bar{X} \pm t_{0.95}\ (\eta-1) \frac{S}{\sqrt{\eta}} , \qquad (47)$$

where the values of t are obtained from Table B-5. For the example data, the values of the upper and lower limits of the 90 percent confidence band are shown in Table B-4. Thus, it is possible to state with 90 percent confidence that the fuel rate for an additional test at 1200 rpm without water addition would lie between 54.86 and 55.54 pounds per hour.

Since the effect of water addition is desired, it is also desirable to employ a test that compares the two samples. It is possible that the two samples selected are a part of the same population; in that case no definite statement could be made concerning the effect of water addition. The goal of the second statistical procedure is a confidence level for the statement that the means of the two populations (without and with water addition) are different.

As a first step, it was assumed that the two population means were equal. The pooled standard deviation was calculated:

TABLE B-5. CUMULATIVE DISTRIBUTION

ν	0.75	0.80	0.85	0.90	0.95	0.975	0.995	0.9995
1	1.0005	1.376	1.963	3.078	6.314	12.706	63.657	636.619
2	0.816	1.061	1.386	1.886	2.920	4.303	8.925	31.598
3	0.765	0.978	1.250	1.638	2.353	3.182	5.841	12.941
4	0.741	0.941	1.190	1.533	2.132	2.776	4.604	8.610
5	0.727	0.920	1.156	1.476	2.015	2.571	4.032	6.859
6	0.718	0.906	1.134	1.440	1.943	2.447	3.707	5.959
7	0.711	0.896	1.119	1.415	1.895	2.365	3.499	5.405
8	0.706	0.889	1.108	1.397	1.860	2.306	3.355	5.041
9	0.703	0.883	1.100	1.383	1.833	2.262	3.250	4.781
10	0.700	0.879	1.093	1.372	1.812	2.228	3.169	4.587
11	0.697	0.876	1.088	1.363	1.796	2.201	3.106	4.437
12	0.695	0.873	1.083	1.356	1.782	2.179	3.055	4.318
13	0.694	0.870	1.079	1.350	1.771	2.160	3.012	4.221
14	0.692	0.868	1.076	1.345	1.761	2.145	2.977	4.140
15	0.691	0.866	1.074	1.341	1.753	2.131	2.947	4.073
16	0.690	0.866	1.071	1.337	1.746	2.120	2.921	4.015
17	0.689	0.863	1.069	1.333	1.740	2.110	2.898	3.965
18	0.688	0.862	1.067	1.330	1.734	2.101	2.878	3.922
19	0.688	0.861	1.066	1.328	1.729	2.093	2.861	3.883
20	0.687	0.860	1.064	1.325	1.725	2.086	2.845	3.850
21	0.686	0.859	1.063	1.323	1.721	2.080	2.831	3.819
22	0.686	0.858	1.061	1.321	1.717	2.074	2.819	3.792
23	0.685	0.858	1.060	1.319	1.714	2.069	2.807	3.767
24	0.685	0.857	1.059	1.318	1.711	2.064	2.797	3.745
25	0.684	0.856	1.058	1.316	1.708	2.060	2.787	3.725
26	0.684	0.856	1.058	1.315	1.706	2.056	2.779	3.707
27	0.684	0.855	1.057	1.314	1.703	2.052	2.771	3.690
28	0.683	0.855	1.056	1.313	1.701	2.048	2.763	3.674
29	0.683	0.854	1.055	1.311	1.699	2.045	2.756	3.659
30	0.683	0.854	1.055	1.310	1.697	2.042	2.750	3.646
35	0.682	0.852	1.052	1.306	1.690	2.030	2.724	3.591
40	0.681	0.851	1.050	1.303	1.684	2.021	2.704	3.551
45	0.680	1.048	1.048	1.301	1.680	2.014	2.690	3.520
50	0.680	0.849	1.047	1.299	1.676	2.008	2.678	3.496
55	0.679	0.849	1.047	1.297	1.673	2.004	2.669	3.476
60	0.679	0.848	1.046	1.296	1.671	2.000	2.660	3.460
70	0.678	0.847	1.045	1.294	1.667	1.994	2.648	3.435
80	0.678	0.847	1.044	1.293	1.665	1.990	2.638	3.416
90	0.678	0.846	1.043	1.291	1.662	1.987	2.632	3.402
100	0.677	0.846	1.042	1.290	1.661	1.984	2.626	3.390
200	0.676	0.844	1.039	1.286	1.653	1.972	2.601	3.340
300	0.676	0.843	1.038	1.285	1.650	1.968	2.592	3.323
400	0.676	0.843	1.038	1.284	1.649	1.966	2.588	3.315
500	0.676	0.843	1.037	1.284	1.684	1.965	2.586	3.310
1000	0.675	0.842	1.037	1.283	1.647	1.962	2.581	3.301
∞	0.67449	0.84162	1.03643	1.28155	1.64485	1.95996	2.57582	3.29053

$$S = \frac{(\eta_1 - 1)\, S_1{}^2 + (\eta_2 - 1)\, S_2{}^2}{\eta_1 + \eta_2 - 2} = 0.3278, \tag{48}$$

where η = sample size

S = sample standard deviation ,

then

$$S_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{S^2}{\eta_1} + \frac{S^2}{\eta_2}} = 0.3194 , \tag{49}$$

and

$$T = \frac{\bar{X}_1 - \bar{X}_2}{S_{\bar{X}_1 - \bar{X}_2}} = 4.2272 , \tag{50}$$

now, if

$$T \leq -t_{(1 - \frac{\alpha}{2})(\eta_1 + \eta_2 - 2)} , \tag{51}$$

or

$$T \geq t_{(1 - \frac{\alpha}{2})(\eta_1 + \eta_2 - 2)} , \tag{52}$$

where α is the probability of rejecting a true hypothesis, then the hypothesis of equal sample means can be rejected. For the present case, using Table B-5,

$$T > t_{(.995)(12)},$$

and

$$1 - \frac{\alpha}{2} = 0.995,$$

imply that $\alpha = 0.01$.

Thus, it is possible to state with 99 percent confidence that the two samples represent different populations and that significance can be attached to the difference between the means.

APPENDIX C

TEST RESULTS

TABLE C-1. ENGINE TEST RESULTS, CUMMINS ENGINE, 900 RPM, BASELINE

DYNAMOMETER CONSTANT: 3000   API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		259.	262.	268.	269.	275.	276.	282.
NOM. WATER PCT.		0.	0.	0.	0.	0.	0.	0.
ENGINE SPEED	RPM	900.	900.	900.	900.	900.	900.	900.
OBS. TORQUE	LB-FT	257.	257.	257.	257.	257.	257.	257.
BAR. PRESS.	IN-HG	28.95	29.14	29.12	29.32	29.25	29.30	29.21
DRY BULB	DEG F	83.	77.	87.	78.	91.	77.	89.
WET BULB	DEG F	69.	66.	66.	66.	68.	61.	65.
REL. HUMIDITY	PCT	49.	56.	32.	53.	30.	39.	26.
CORR. BHP	HP	44.9	44.1	44.8	43.9	44.8	43.6	44.6
CORR. BMEP	PSI	23.1	22.7	23.1	22.6	23.0	22.5	23.0
FUEL FLOW	LB/HR	25.12	25.11	24.73	25.52	25.24	24.70	24.85
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BSFC	LB/BHP-HR	5590	.5692	.5516	.5817	.5635	.5662	.5570
AIR FLOW	LB/MIN	26.1	26.5	26.0	26.3	26.1	26.6	26.1
COOLANT IN	DEG F	183.	174.	179.	179.	181.	178.	176.
COOLANT OUT	DEG F	188.	184.	185.	185.	186.	184.	183.
OIL SUMP	DEG F	194.	188.	193.	192.	193.	189.	191.
FUEL IN	DEG F	90.	90.	93.	89.	95.	92.	92.
FUEL RETURN	DEG F	137.	135.	151.	143.	150.	142.	145.
FUEL SUPPLY	DEG F	111.	106.	108.	104.	107.	104.	107.
FUEL COOLER	DEG F	87.	90.	91.	88.	95.	95.	90.
INTAKE AIR	DEG F	83.	75.	90.	76.	92.	75.	90.
TURB. INLET (L)	DEG F	457.	450.	467.	448.	464.	447.	464.
TURB. INLET (R)	DEG F	480.	471.	482.	468.	482.	464.	478.
COMP. OUT (L)	DEG F	101.	92.	107.	93.	110.	92.	107.
COMP. OUT (R)	DEG F	104.	97.	112.	93.	110.	95.	107.
CHARGE AIR (L)	DEG F	174.	168.	174.	172.	176.	170.	172.
CHARGE AIR (R)	DEG F	177.	170.	176.	174.	177.	173.	174.
EXH. STACK (R)	DEG F	444.	435.	446.	433.	445.	430.	441.
EXH. STACK (L)	DEG F	425.	419.	434.	416.	431.	415.	430.
WATER INLET	DEG F	91.	84.	93.	83.	97.	80.	97.
CELL AIR	DEG F	80.	77.	90.	80.	92.	78.	90.
EXHAUST 1R	DEG F	559.	553.	561.	555.	560.	551.	557.
EXHAUST 2R	DEG F	433.	429.	442.	434.	445.	426.	431.
EXHAUST 3R	DEG F	439.	421.	438.	427.	427.	419.	422.
EXHAUST 4R	DEG F	513.	566.	509.	508.	511.	502.	510.
EXHAUST 5R	DEG F	486.	480.	489.	483.	491.	479.	497.
EXHAUST 6R	DEG F	534.	527.	545.	532.	541.	538.	540.
EXHAUST 1L	DEG F	458.	450.	465.	457.	460.	457.	463.
EXHAUST 2L	DEG F	529.	534.	540.	530.	529.	535.	537.
EXHAUST 3L	DEG F	435.	427.	443.	427.	439.	429.	438.
EXHAUST 4L	DEG F	440.	426.	439.	428.	443.	432.	439.
EXHAUST 5L	DEG F	551.	550.	566.	551.	549.	546.	558.
EXHAUST 6L	DEG F	472.	466.	490.	471.	486.	479.	488.
OIL PRESSURE	PSI	48.	50.	48.	48.	48.	50.	49.
RAIL PRESSURE	PSI	5.0	6.0	6.0	6.0	6.0	6.0	6.0
BOOST (R)	PSI	.5	.5	.5	.5	.5	.5	.5
BOOST (L)	PSI	1.0	.9	1.0	1.5	1.5	1.5	1.0
INLET VAC. (R)	IN-H2O	2.2	2.2	2.2	2.1	1.0	2.1	2.2
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (R)	IN-HG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (L)	IN-HG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FUEL PRESS.	PSI	20.	20.	20.	20.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.	3.	3.	2.	3.	3.	3.
WATER PRESS.	PSI	0.	0.	0.	0.	0.	0.	0.

TABLE C-2. ENGINE TEST RESULTS, CUMMINS ENGINE, 900 RPM, 5% WATER

DYNAMOMETER CONSTANT: 3000   API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		260.	263.	270.	277.
NOM. WATER PCT		5.	5.	5.	5.
ENGINE SPEED	RPM	900.	900.	900.	900
OBS. TORQUE	LB-FT	257.	257.	257.	257.
BAR. PRESS.	IN-HG	28.90	29.15	29.34	29.31
DRY BULB	DEG F	85.	77.	78.	77.
WET BULB	DEG F	70.	66.	66.	61.
REL. HUMIDITY	PCT	47.	56.	53.	39
CORR. BHP	HP	45.3	44.3	44.1	43.8
CORR. BMEP	PSI	23.3	22.8	22.7	22.5
FUEL FLOW	LB/HR	24.82	25.06	24.89	24.73
WATER FLOW	CC/MIN	11.5	10.5	11.1	10.5
CALC. VOL. %	PCT	4.9	4.4	4.7	4.5
BSFC	LB/BHP-HR	.5483	.5652	.5646	.5647
AIR FLOW	LB/MIN	25.6	26.2	26.4	26.4
COOLANT IN	DEG F	182.	179.	179.	177.
COOLANT OUT	DEG F	187.	185.	184.	184.
OIL SUMP	DEG F	194.	191.	192.	190.
FUEL IN	DEG F	99.	99.	92.	92.
FUEL RETURN	DEG F	151.	147.	146.	145.
FUEL SUPPLY	DEG F	114.	109.	107.	107
FUEL COOLER	DEG F	96.	90.	91.	90.
INTAKE AIR	DEG F	87.	79.	80.	78.
TURB. INLET (L)	DEG F	448.	458.	448.	448.
TURB. INLET (R)	DEG F	467.	476.	469.	466.
COMP. OUT (L)	DEG F	104.	96.	97.	95.
COMP. OUT (R)	DEG F	107.	98.	97.	95.
CHARGE AIR (L)	DEG F	174.	172.	173.	171.
CHARGE AIR (R)	DEG F	177.	175.	175.	174.
EXH. STACK (R)	DEG F	434.	440.	434.	433.
EXH. STACK (L)	DEG F	419.	425.	416.	417.
WATER INLET	DEG F	94.	85.	84.	84.
CELL AIR	DEG F	86.	80.	81.	79.
EXHAUST 1R	DEG F	563.	560.	548.	549.
EXHAUST 2R	DEG F	435.	433.	430.	424.
EXHAUST 3R	DEG F	430.	429.	426.	419.
EXHAUST 4R	DEG F	497.	499.	491.	495.
EXHAUST 5R	DEG F	471.	484.	470.	477.
EXHAUST 6R	DEG F	540.	530.	526.	527.
EXHAUST 1L	DEG F	464.	466.	454.	461.
EXHAUST 2L	DEG F	533.	535.	525.	528.
EXHAUST 3L	DEG F	432.	436.	430.	433.
EXHAUST 4L	DEG F	425.	431.	425.	426.
EXHAUST 5L	DEG F	545.	533.	536.	533.
EXHAUST 6L	DEG F	475.	473.	471.	468.
OIL PRESSURE	PSI	48.	48.	48.	49.
RAIL PRESSURE	PSI	6.0	6.0	6.0	6.0
BOOST (R)	PSI	.5	.5	.5	.5
BOOST (L)	PSI	1.2	1.0	1.5	1.5
INLET VAC. (R)	IN-H2O	2.3	2.2	2.2	2.2
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0
TURB. IN. (R)	IN-HG	0.0	0.0	0.0	0.0
TURB. IN. (L)	IN-HG	0.0	0.0	0.0	0.0
FUEL PRESS.	PSI	20.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	3.	3.	3.
WATER PRESS.	PSI	60.	60.	60.	60.

TABLE C-3. ENGINE TEST RESULTS, CUMMINS ENGINE, 900 RPM, 10% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		261.	264.	271.	278.
NOM. WATER PCT.		10.	10.	10.	10.
ENGINE SPEED	RPM	900.	900.	900.	900.
OBS. TORQUE	LB-FT	257.	257.	257.	257.
BAR. PRESS.	IN-HG	28.89	29.15	29.35	29.32
DRY BULB	DEG F	85.	82.	82.	80.
WET BULB	DEG F	70.	66.	67.	64.
REL. HUMIDITY	PCT	48.	43.	46.	41.
CORR. BHP	HP	45.4	44.5	44.2	44.0
CORR. BMEP	PSI	23.4	22.9	22.7	22.6
FUEL FLOW	LB/HR	24.87	25.03	25.31	24.89
WATER FLOW	CC/MIN	17.3	19.7	19.7	19.7
CALC. VOL. %	PCT	7.1	8.0	7.9	8.1
BSFC	LB/BHP-HR	.5479	.5627	.5731	.5660
AIR FLOW	LB/MIN	25.6	26.2	26.2	26.6
COOLANT IN	DEG F	184.	178.	179.	174.
COOLANT OUT	DEG F	189.	184.	184.	180.
OIL SUMP	DEG F	195.	191.	192.	187.
FUEL IN	DEG F	102.	92.	94.	93.
FUEL RETURN	DEG F	155.	111.	148.	146.
FUEL SUPPLY	DEG F	114.	147.	111.	109.
FUEL COOLER	DEG F	101.	90.	92.	92.
INTAKE AIR	DEG F	89.	83.	82.	80.
TURB. INLET (L)	DEG F	442.	445.	440.	439.
TURB. INLET (R)	DEG F	467.	463.	461.	457.
COMP. OUT (L)	DEG F	106.	99.	99.	96.
COMP. OUT (R)	DEG F	110.	104.	99.	96.
CHARGE AIR (L)	DEG F	176.	172.	173.	168.
CHARGE AIR (R)	DEG F	178.	174.	175.	171.
EXH. STACK (R)	DEG F	433.	430.	427.	424.
EXH. STACK (L)	DEG F	412.	415.	409.	408.
WATER INLET	DEG F	92.	86.	84.	82.
CELL AIR	DEG F	88.	81.	83.	80.
EXHAUST 1R	DEG F	551.	550.	544.	538.
EXHAUST 2R	DEG F	438.	434.	427.	425.
EXHAUST 3R	DEG F	417.	423.	421.	413.
EXHAUST 4R	DEG F	494.	496.	492.	489.
EXHAUST 5R	DEG F	475.	470.	465.	474.
EXHAUST 6R	DEG F	527.	523.	521.	516.
EXHAUST 1L	DEG F	466.	464.	460.	454.
EXHAUST 2L	DEG F	515.	524.	519.	519.
EXHAUST 3L	DEG F	425.	432.	426.	420.
EXHAUST 4L	DEG F	414.	429.	421.	418.
EXHAUST 5L	DEG F	535.	531.	528.	530.
EXHAUST 6L	DEG F	470.	462.	464.	463.
OIL PRESSURE	PSI	47.	49.	48.	50.
RAIL PRESSURE	PSI	7.0	7.0	7.0	7.0
BOOST (R)	PSI	.5	.5	.5	.5
BOOST (L)	PSI	1.2	1.0	1.5	1.5
INLET VAC. (R)	IN-H2O	2.3	2.2	2.2	2.2
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0
TURB. IN. (R)	IN-HG	0.0	0.0	0.0	0.0
TURB. IN. (L)	IN-HG	0.0	0.0	0.0	0.0
FUEL PRESS.	PSI	20.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	3.	3.	3.
WATER PRESS.	PSI	50.	60.	60.	60.

TABLE C-4. ENGINE TEST RESULTS, CUMMINS ENGINE, 900 RPM, 15% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		265.	272.	279.
NOM. WATER PCT.		15.	15.	15.
ENGINE SPEED	RPM	900.	900.	900.
OBS. TORQUE	LB-FT	257.	257.	257.
BAR. PRESS.	IN-HG	29.15	29.34	29.30
DRY BULB	DEG F	83.	87.	84.
WET BULB	DEG F	67.	68.	66.
REL. HUMIDITY	PCT	43.	37.	38.
CORR. BHP	HP	44.6	44.4	44.3
CORR. BMEP	PSI	22.9	22.8	22.8
FUEL FLOW	LB/HR	24.50	24.29	24.46
WATER FLOW	CC/MIN	33.8	33.8	33.8
CALC. VOL. %	PCT.	13.2	13.3	13.2
BSFC	LB/BHP-HR	.5498	.5474	.5526
AIR FLOW	LB/MIN	26.1	26.3	26.3
COOLANT IN	DEG F	179.	180.	178.
COOLANT OUT	DEG F	185.	185.	184.
OIL SUMP	DEG F	192.	192.	190.
FUEL IN	DEG F	92.	97.	99.
FUEL RETURN	DEG F	112.	150.	152.
FUEL SUPPLY	DEG F	149.	112.	109.
FUEL COOLER	DEG F	90.	95.	97.
INTAKE AIR	DEG F	84.	86.	84.
TURB. INLET (L)	DEG F	440.	435.	435.
TURB. INLET (R)	DEG F	459.	457.	455.
COMP. OUT (L)	DEG F	100.	102.	100.
COMP. OUT (R)	DEG F	105.	102.	100.
CHARGE AIR (L)	DEG F	174.	174.	173.
CHARGE AIR (R)	DEG F	176.	176.	175.
EXH. STACK (R)	DEG F	425.	424.	423.
EXH. STACK (L)	DEG F	409.	406.	406.
WATER INLET	DEG F	88.	89.	86.
CELL AIR	DEG F	83.	86.	85.
EXHAUST 1R	DEG F	540.	538.	537.
EXHAUST 2R	DEG F	429.	427.	427.
EXHAUST 3R	DEG F	420.	416.	415.
EXHAUST 4R	DEG F	491.	489.	488.
EXHAUST 5R	DEG F	467.	471.	470.
EXHAUST 6R	DEG F	514.	519.	517.
EXHAUST 1L	DEG F	463.	458.	457.
EXHAUST 2L	DEG F	511.	508.	510.
EXHAUST 3L	DEG F	419.	417.	420.
EXHAUST 4L	DEG F	425.	421.	423.
EXHAUST 5L	DEG F	530.	526.	529.
EXHAUST 6L	DEG F	455.	461.	464.
OIL PRESSURE	PSI	48.	48.	49.
RAIL PRESSURE	PSI	7.0	7.0	7.0
BOOST (R)	PSI	.5	.5	.5
BOOST (L)	PSI	.8	1.5	1.5
INLET VAC. (R)	IN-H2O	2.2	2.2	2.2
EXH. PRESS. (R)	PSI	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0
TURB. IN. (R)	IN-HG	0.0	0.0	0.0
TURB. IN. (L)	IN-HG	0.0	0.0	0.0
FUEL PRESS.	PSI	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.
FUEL SUPPLY	PSI	3.	3.	3.
WATER PRESS.	PSI	60.	60.	60.

TABLE C-5. ENGINE TEST RESULTS, CUMMINS ENGINE, 900 RPM, 20% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		266.	273.	280.
NOM. WATER PCT.		20.	20.	20.
ENGINE SPEED	RPM	900.	900.	900.
OBS. TORQUE	LB-FT	257.	257.	257.
BAR. PRESS.	IN-HG	29.14	29.32	29.28
DRY BULB	DEG F	83.	87.	84.
WET BULB	DEG F	67.	68.	66.
REL. HUMIDITY	PCT	43.	37.	38.
CORR. BHP	HP	44.7	44.5	44.4
CORR. BMEP	PSI	23.0	22.9	22.8
FUEL FLOW	LB/HR	24.45	24.81	24.68
WATER FLOW	CC/MIN	49.8	49.8	49.8
CALC. VOL. %	PCT.	18.4	18.1	18.2
BSFC	LB/BHP-HR	.5469	.5573	.5565
AIR FLOW	LB/MIN	25.7	26.2	26.2
COOLANT IN	DEG F	179.	180.	176.
COOLANT OUT	DEG F	184.	186.	183.
OIL SUMP	DEG F	192.	192.	190.
FUEL IN	DEG F	94.	99.	95.
FUEL RETURN	DEG F	151.	152.	152.
FUEL SUPPLY	DEG F	115.	122.	113.
FUEL COOLER	DEG F	92.	98.	93.
INTAKE AIR	DEG F	86.	88.	85.
TURB. INLET (L)	DEG F	432.	426.	424.
TURB. INLET (R)	DEG F	448.	448.	443.
COMP. OUT (L)	DEG F	102.	104.	102.
COMP. OUT (R)	DEG F	107.	104.	102.
CHARGE AIR (L)	DEG F	174.	175.	172.
CHARGE AIR (R)	DEG F	176.	177.	174.
EXH. STACK (R)	DEG F	415.	415.	412.
EXH. STACK (L)	DEG F	402.	397.	396.
WATER INLET	DEG F	90.	89.	88.
CELL AIR	DEG F	85.	89.	87.
EXHAUST 1R	DEG F	520.	518.	516.
EXHAUST 2R	DEG F	411.	404.	409.
EXHAUST 3R	DEG F	412.	409.	406.
EXHAUST 4R	DEG F	483.	482.	477.
EXHAUST 5R	DEG F	457.	460.	463.
EXHAUST 6R	DEG F	502.	505.	501.
EXHAUST 1L	DEG F	455.	452.	450.
EXHAUST 2L	DEG F	488.	484.	486.
EXHAUST 3L	DEG F	408.	407.	405.
EXHAUST 4L	DEG F	414.	409.	411.
EXHAUST 5L	DEG F	515.	509.	507.
EXHAUST 6L	DEG F	440.	441.	432.
OIL PRESSURE	PSI	48.	48.	49.
RAIL PRESSURE	PSI	7.5	8.0	8.0
BOOST (R)	PSI	.5	.5	.5
BOOST (L)	PSI	.9	1.5	1.5
INLET VAC. (R)	IN-H2O	2.2	2.2	2.2
EXH. PRESS. (R)	PSI	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0
TURB. IN. (R)	IN-HG	0.0	0.0	0.0
TURB. IN. (L)	IN-HG	0.0	0.0	0.0
FUEL PRESS.	PSI	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.
FUEL SUPPLY	PSI	3.	3.	3.
WATER PRESS.	PSI	60.	60.	60.

TABLE C-6. ENGINE TEST RESULTS, CUMMINS ENGINE, 900 RPM, 25% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		267.	274.	281.
NOM. WATER PCT.		25.	25.	25.
ENGINE SPEED	RPM	900.	900.	900.
OBS. TORQUE	LB-FT	257.	257.	257.
BAR. PRESS	IN-HG	29.13	29.29	29.25
DRY BULB	DEG F	87.	90.	88.
WET BULB	DEG F	66.	69.	65.
REL. HUMIDITY	PCT	32.	34.	28.
CORR. BHP	HP	44.7	44.7	44.5
CORR. BMEP	PSI	23.0	23.0	22.9
FUEL FLOW	LB/HR	25.16	24.84	24.73
WATER FLOW	CC/MIN	66.4	66.4	66.4
CALC. VOL. %	PCT	22.6	22.7	22.9
BSFC	LB/BHP-HR	.5628	.5560	.5562
AIR FLOW	LB/MIN	26.0	26.2	26.1
COOLANT IN	DEG F	183.	181.	176.
COOLANT OUT	DEG F	188.	187.	182.
OIL SUMP	DEG F	194.	193.	189.
FUEL IN	DEG F	95.	100.	95.
FUEL RETURN	DEG F	154.	155.	151.
FUEL SUPPLY	DEG F	112.	114.	113.
FUEL COOLER	DEG F	93.	100.	94.
INTAKE AIR	DEG F	88.	90.	88.
TURB. INLET (L)	DEG F	428.	426.	421.
TURB. INLET (R)	DEG F	443.	445.	440.
COMP. OUT (L)	DEG F	105.	107.	104.
COMP. OUT (R)	DEG F	110.	107.	104.
CHARGE AIR (L)	DEG F	176.	176.	172.
CHARGE AIR (R)	DEG F	178.	178.	174.
EXH. STACK (R)	DEG F	411.	412.	407.
EXH. STACK (L)	DEG F	400.	398.	393.
WATER INLET	DEG F	89.	90.	88.
CELL AIR	DEG F	88.	90.	88.
EXHAUST 1R	DEG F	507.	510.	509.
EXHAUST 2R	DEG F	406.	403.	396.
EXHAUST 3R	DEG F	412.	411.	406.
EXHAUST 4R	DEG F	473.	481.	473.
EXHAUST 5R	DEG F	450.	461.	460.
EXHAUST 6R	DEG F	495.	499.	492.
EXHAUST 1L	DEG F	450.	450.	446.
EXHAUST 2L	DEG F	483.	481.	477.
EXHAUST 3L	DEG F	411.	412.	410.
EXHAUST 4L	DEG F	411.	413.	409.
EXHAUST 5L	DEG F	496.	503.	491.
EXHAUST 6L	DEG F	432.	439.	432.
OIL PRESSURE	PSI	48.	48.	50.
RAIL PRESSURE	PSI	8.0	9.0	8.0
BOOST (R)	PSI	.5	.5	.5
BOOST (L)	PSI	.9	1.5	1.5
INLET VAC. (R)	IN-H2O	2.2	2.2	2.2
EXH. PRESS. (R)	PSI	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0
TURB. IN. (R)	IN-HG	0.0	0.0	0.0
TURB. IN. (L)	IN-HG	0.0	0.0	0.0
FUEL PRESS.	PSI	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	0.
FUEL SUPPLY	PSI	3.	3.	3.
WATER PRESS.	PSI	60.	60.	60.

TABLE C-7. ENGINE TEST RESULTS, CUMMINS ENGINE, 1200 RPM, BASELINE

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		178.	188.	194.	224.	230.	238.	244.	252.	258.
NOM. WATER PCT.		0.	0.	0.	0.	0.	0.	0.	0.	0.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.	1200.	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	508.	508.	508.	508.	508.	508.	508.	508.	508.
BAR. PRESS.	IN-HG	29.33	29.11	29.17	29.03	29.03	28.95	28.92	29.01	29.10
DRY BULB	DEG F	78.	73.	81.	82.	89.	86.	100.	82.	81.
WET BULB	DEG F	63.	68.	72.	76.	76.	76.	78.	77.	74.
REL. HUMIDITY	PCT	43.	78.	65.	76.	55.	63.	38.	80.	72.
CORR. BHP	HP	115.4	116.2	117.5	118.9	119.9	119.8	121.6	119.4	117.8
CORR. BMEP	PSI	44.6	44.8	45.4	45.9	46.3	46.2	46.9	46.1	45.5
FUEL FLOW	LB/HR	54.72	55.30	54.43	54.84	55.04	54.94	55.58	56.01	55.94
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BSFC	LB/BHP-HR	.4740	.4761	.4631	.4613	.4589	.4586	.4570	.4689	.4748
AIR FLOW	LB/MIN	38.4	38.0	37.3	36.5	36.8	37.3	36.7	36.9	37.3
STOICH. F/A		.0691	.0691	.0691	.0691	.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0237	.0242	.0243	.0250	.0249	.0245	.0252	.0253	.0250
CALC. F/A		.0256	.0248	.0250	.0246	.0245	.0250	.0255	.0235	.0252
% DIFF.	PCT	8.07	2.37	2.74	-1.67	-1.80	2.07	1.18	-7.14	.61
COOLANT IN	DEG F	169.	172.	173.	176.	177.	174.	170.	176.	177.
COOLANT OUT	DEG F	180.	181.	182.	185.	185.	183.	180.	184.	185.
OIL SUMP	DEG F	194.	194.	197.	198.	200.	195.	195.	198.	199.
FUEL IN	DEG F	93.	92.	95.	100.	103.	99.	103.	102.	96.
FUEL RETURN	DEG F	147.	149.	152.	149.	152.	149.	150.	149.	150.
FUEL SUPPLY	DEG F	91.	94.	102.	102.	109.	104.	109.	103.	95.
FUEL COOLER	DEG F	90.	90.	91.	96.	96.	96.	98.	99.	94.
INTAKE AIR	DEG F	79.	72.	81.	82.	91.	87.	100.	84.	79.
TURB. INLET (L)	DEG F	649.	629.	637.	663.	658.	658.	677.	664.	657.
TURB. INLET (R)	DEG F	639.	657.	660.	655.	684.	658.	657.	659.	682.
COMP. OUT (L)	DEG F	112.	106.	112.	113.	123.	118.	131.	114.	111.
COMP. OUT (R)	DEG F	111.	105.	112.	112.	122.	118.	131.	114.	111.
CHARGE AIR (L)	DEG F	167.	168.	169.	170.	172.	169.	169.	170.	171.
CHARGE AIR (R)	DEG F	168.	169.	170.	172.	174.	170.	170.	171.	173.
EXH. STACK (R)	DEG F	584.	599.	601.	598.	622.	600.	604.	603.	620.
EXH. STACK (L)	DEG F	594.	574.	579.	605.	599.	599.	621.	605.	600.
WATER INLET	DEG F	81.	75.	86.	86.	94.	87.	103.	85.	86.
CELL AIR	DEG F	78.	76.	80.	85.	92.	90.	101.	87.	80.
EXHAUST 1R	DEG F	662.	713.	701.	711.	715.	709.	698.	706.	714.
EXHAUST 2R	DEG F	509.	598.	568.	583.	581.	568.	563.	585.	595.
EXHAUST 3R	DEG F	607.	600.	621.	588.	627.	614.	618.	608.	640.
EXHAUST 4R	DEG F	677.	669.	680.	682.	690.	680.	679.	704.	692.
EXHAUST 5R	DEG F	642.	654.	661.	653.	671.	643.	633.	657.	653.
EXHAUST 6R	DEG F	698.	711.	715.	709.	735.	704.	692.	703.	711.
EXHAUST 1L	DEG F	663.	655.	632.	690.	653.	670.	689.	674.	657.
EXHAUST 2L	DEG F	715.	678.	655.	692.	666.	712.	697.	706.	701.
EXHAUST 3L	DEG F	613.	601.	623.	621.	642.	616.	643.	630.	620.
EXHAUST 4L	DEG F	627.	618.	626.	640.	633.	626.	644.	645.	628.
EXHAUST 5L	DEG F	714.	639.	670.	709.	680.	714.	720.	706.	716.
EXHAUST 6L	DEG F	680.	679.	690.	683.	702.	689.	701.	694.	0.
OIL PRESSURE	PSI	65.	66.	64.	64.	64.	66.	66.	65.	64.
RAIL PRESSURE	PSI	14.9	149.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
BOOST (R)	PSI	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
BOOST (L)	PSI	2.6	2.5	2.5	2.5	2.6	2.5	2.5	2.4	2.0
INLET VAC. (R)	IN-H2O	3.6	3.8	3.9	4.2	4.3	4.5	4.8	5.0	5.4
EXH. PRESS. (R)	PSI	.1	.1	.1	0.0	0.0	0.0	0.0	0.0	.1
EXH. PRESS. (L)	PSI	.1	.1	.1	.1	.1	1.0	1.0	.1	.2
TURB. IN. (R)	IN-HG	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
TURB. IN. (L)	IN-HG	1.4	1.4	1.5	1.5	1.5	1.4	1.5	1.5	1.5
FUEL PRESS.	PSI	18.	21.	20.	20.	20.	20.	20.	20.	22.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	2.	2.	2.	2.	2.	2.	2.
WATER PRESS.	PSI	0.	0.	0.	0.	0.	0.	0.	0.	0.
HYDROCARBONS	PPMC	96.	54.	84.	77.	124.	120.	117.	70.	59.
CARBON MONOXIDE	PPM	488.	212.	508.	281.	199.	233.	239.	239.	233.
NITRIC OXIDE	PPM	340.	288.	263.	213.	229.	217.	239.	174.	225.
NITROGEN OXIDES	PPM	355.	313.	288.	234.	251.	230.	258.	190.	240.
CARBON DIOXIDE	PCT	5.4	5.3	5.3	5.3	5.2	5.3	5.5	5.0	5.4
OXYGEN	PCT	14.3	15.8	15.8	11.6	9.9	13.9	15.6	13.6	15.2
SMOKE OPACITY	PCT	7.5	8.6	8.7	9.6	12.5	10.2	10.5	9.5	10.5
HC MASS	GM-HR	45.656	26.649	40.645	37.936	62.050	58.433	56.697	37.212	29.219
CO MASS	GM-HR	446.11	203.00	475.09	268.15	192.15	218.68	223.13	244.86	221.67
NOX MASS	GM-HR	521.20	535.94	484.32	431.38	441.54	404.88	419.61	383.03	427.38
BSHC	GM/BHP-HR	.3955	.2294	.3459	.3191	.5174	.4878	.4662	.3116	.2480
BSCO	GM/BHP-HR	3.8642	1.7475	4.0426	2.2558	1.6023	1.8255	1.8348	2.0501	1.8813
BSNO	GM/BHP-HR	4.5146	4.6137	4.1211	3.6290	3.6818	3.3799	3.4504	3.2069	3.6272

TABLE C-8. ENGINE TEST RESULTS, CUMMINS ENGINE, 1200 RPM, 5% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		179.	189.	225.	239.	253
NOM. WATER PCT.		5.	5	5.	5.	5
ENGINE SPEED	RPM	1200.	1200.	1200	1200	1200.
OBS. TORQUE	LB-FT	508.	508.	508.	508	508.
BAR. PRESS.	IN-HG	29.32	29.14	29.04	28.97	29.02
DRY BULB	DEG F	78.	73.	82.	86	82.
WET BULB	DEG F	63.	68.	76.	76	77
REL. HUMIDITY	PCT	43.	78.	76.	63.	80.
CORR. BHP	HP	115.6	116.2	118.7	120.0	119.5
CORR. BMEP	PSI	44.6	44.8	45.8	46.3	46.1
FUEL FLOW	LB/HR	54.66	54.55	54.86	54.48	55.53
WATER FLOW	CC/MIN	23.7	23.7	25.0	23.7	18.5
CALC. VOL. %	PCT.	4.6	4.6	4.8	4.6	3.5
BSFC	LB/BHP-HR	.4727	.4694	.4622	.4539	.4645
AIR FLOW	LB/MIN	38.4	38.0	35.7	37.1	36.9
STOICH. F/A		.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0237	.0240	.0256	.0245	.0251
CALC. F/A		.0252	.0246	.0244	.0250	.0245
% DIFF.	PCT	6.05	2.61	-4.78	2.34	-2.35
COOLANT IN	DEG F	168.	173.	176.	171	176.
COOLANT OUT	DEG F	179.	182.	185.	181	184.
OIL SUMP	DEG F	195.	196.	199.	196	198
FUEL IN	DEG F	95.	95.	100.	100.	99
FUEL RETURN	DEG F	148.	150.	149.	149	149.
FUEL SUPPLY	DEG F	93.	95.	103.	106.	102.
FUEL COOLER	DEG F	92.	92.	97.	96.	95.
INTAKE AIR	DEG F	80.	73.	81.	89	85.
TURB. INLET (L)	DEG F	646.	619.	643.	657.	653.
TURB. INLET (R)	DEG F	628.	649.	658.	647.	652.
COMP. OUT (L)	DEG F	112.	105.	112.	120	116.
COMP. OUT (R)	DEG F	112.	105.	112.	121.	117.
CHARGE AIR (L)	DEG F	166.	168.	171.	170.	170.
CHARGE AIR (R)	DEG F	168.	169.	172.	171.	172.
EXH. STACK (R)	DEG F	574.	591.	597.	590	596.
EXH. STACK (L)	DEG F	591.	564.	585.	600.	597.
WATER INLET	DEG F	83.	75.	84.	93	85.
CELL AIR	DEG F	78.	75.	84.	90	86.
EXHAUST 1R	DEG F	673.	704.	713.	696.	695.
EXHAUST 2R	DEG F	549.	587.	595.	572.	587
EXHAUST 3R	DEG F	602.	606.	601.	600	605
EXHAUST 4R	DEG F	650.	659.	666.	662.	655.
EXHAUST 5R	DEG F	623.	621.	636.	634	644
EXHAUST 6R	DEG F	677.	687.	708.	703.	702.
EXHAUST 1L	DEG F	655.	628.	647.	677.	666
EXHAUST 2L	DEG F	688.	639.	654.	704.	692
EXHAUST 3L	DEG F	627.	609.	624.	627.	621.
EXHAUST 4L	DEG F	630.	614.	624.	629.	632.
EXHAUST 5L	DEG F	687.	659.	697.	709	692
EXHAUST 6L	DEG F	681.	672.	677.	693.	680.
OIL PRESSURE	PSI	66.	65.	64	65.	65.
RAIL PRESSURE	PSI	15.0	15.0	15.0	15.0	15.0
BOOST (R)	PSI	1.8	1.8	1.8	1.8	1.8
BOOST (L)	PSI	2.6	2.5	2.5	2.5	2.3
INLET VAC. (R)	IN-H2O	3.7	3.8	4.2	4.6	5.3
EXH. PRESS. (R)	PSI	.1	1.0	0.0	0.0	.1
EXH. PRESS. (L)	PSI	.1	1.0	.1	1.0	.2
TURB. IN. (R)	IN-HG	2.5	2.5	2.5	2.5	2.5
TURB. IN. (L)	IN-HG	1.3	1.4	1.5	1.5	1.4
FUEL PRESS.	PSI	18.	22.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100	100.
FUEL SUPPLY	PSI	2.	2.	2.	2	2.
WATER PRESS.	PSI	60.	50.	60.	60.	60.
HYDROCARBONS	PPMC	105.	70.	107	142	38.
CARBON MONOXIDE	PPM	239.	488.	267	219	219
NITRIC OXIDE	PPM	330.	275.	210.	214.	178.
NITROGEN OXIDES	PPM	350.	300.	231.	235.	198.
CARBON DIOXIDE	PCT	5.4	5.2	5.2	5.3	5.2
OXYGEN	PCT	13.7	16.0	11.6	14.0	13.9
SMOKE OPACITY	PCT	5.5	5.6	6.0	8.0	6.5
HC MASS	GM-HR	50.691	34.560	54.561	68.819	44.503
CO MASS	GM-HR	222.69	464.32	257.26	204.27	213.32
NOX MASS	GM-HR	537.09	527.91	444.20	423.10	390.01
BSHC	GM/BHP-HR	.4384	.2974	.4597	.5734	.3723
BSCO	GM/BHP-HR	1.9258	3.9961	2.1678	1.7020	1.7844
BSNO	GM/BHP-HR	4.6447	4.5434	3.7430	3.5254	3.2623

TABLE C-9. ENGINE TEST RESULTS, CUMMINS ENGINE, 1200 RPM, 10% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		180.	190.	226.	240.	254.
NOM. WATER PCT.		10.	10.	10.	10.	10.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	508.	508.	508.	508.	508.
BAR. PRESS.	IN-HG	29.31	29.14	29.05	28.96	29.04
DRY BULB	DEG F	80.	74.	82.	92.	86.
WET BULB	DEG F	65.	68.	75.	78.	79.
REL. HUMIDITY	PCT	44.	74.	72.	54.	74.
CORR. BHP	HP	116.1	116.1	118.5	120.6	119.6
CORR. BMEP	PSI	44.8	44.8	45.7	46.5	46.2
FUEL FLOW	LB/HR	53.63	53.71	54.38	53.90	55.02
WATER FLOW	CC/MIN	49.8	49.8	49.8	49.8	49.8
CALC. VOL. %	PCT.	9.3	9.3	9.2	9.2	9.1
BSFC	LB/BHP-HR	.4617	.4624	.4591	.4470	.4599
AIR FLOW	LB/MIN	37.2	37.9	37.1	36.5	36.7
STOICH. F/A		.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0240	.0236	.0245	.0246	.0250
CALC. F/A		.0249	.0242	.0240	.0252	.0235
% DIFF.	PCT	3.57	2.52	-2.03	2.37	-6.06
COOLANT IN	DEG F	170.	173.	177.	172.	176.
COOLANT OUT	DEG F	181.	181.	185.	182.	184.
OIL SUMP	DEG F	196.	196.	199.	196.	198.
FUEL IN	DEG F	97.	96.	100.	103.	100.
FUEL RETURN	DEG F	150.	150.	148.	149.	148.
FUEL SUPPLY	DEG F	96.	99.	104.	109.	102.
FUEL COOLER	DEG F	96.	93.	96.	98.	96.
INTAKE AIR	DEG F	82.	73.	81.	92.	85.
TURB. INLET (L)	DEG F	633.	611.	628.	639.	632.
TURB. INLET (R)	DEG F	621.	630.	645.	628.	639.
COMP. OUT (L)	DEG F	114.	104.	112.	122.	115.
COMP. OUT (R)	DEG F	113.	104.	112.	123.	117.
CHARGE AIR (L)	DEG F	168.	168.	170.	179.	170.
CHARGE AIR (R)	DEG F	169.	169.	172.	171.	172.
EXH. STACK (R)	DEG F	568.	575.	587.	573.	583.
EXH. STACK (L)	DEG F	578.	557.	572.	585.	578.
WATER INLET	DEG F	85.	79.	85.	95.	86.
CELL AIR	DEG F	81.	74.	84.	93.	86.
EXHAUST 1R	DEG F	661.	674.	684.	670.	690.
EXHAUST 2R	DEG F	551.	568.	572.	557.	588.
EXHAUST 3R	DEG F	592.	603.	601.	591.	598.
EXHAUST 4R	DEG F	638.	650.	663.	650.	640.
EXHAUST 5R	DEG F	618.	620.	642.	623.	640.
EXHAUST 6R	DEG F	675.	680.	698.	677.	693.
EXHAUST 1L	DEG F	641.	625.	634.	688.	659.
EXHAUST 2L	DEG F	673.	637.	638.	683.	680.
EXHAUST 3L	DEG F	609.	603.	611.	614.	608.
EXHAUST 4L	DEG F	613.	602.	608.	615.	612.
EXHAUST 5L	DEG F	671.	651.	690.	686.	678.
EXHAUST 6L	DEG F	667.	652.	670.	671.	665.
OIL PRESSURE	PSI	65.	65.	64.	63.	65.
RAIL PRESSURE	PSI	15.2	15.2	17.0	15.0	16.0
BOOST (R)	PSI	1.8	1.8	1.7	1.7	1.6
BOOST (L)	PSI	2.8	2.5	2.5	2.5	2.3
INLET VAC. (R)	IN-H2O	3.7	3.8	4.2	4.6	5.3
EXH. PRESS. (R)	PSI	.1	.1	0.0	0.0	.1
EXH. PRESS. (L)	PSI	.1	.1	.1	.1	.2
TURB. IN. (R)	IN-HG	2.7	2.5	2.5	2.5	2.3
TURB. IN. (L)	IN-HG	1.2	1.4	1.3	1.4	1.7
FUEL PRESS.	PSI	18.	22.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	24.	2.	2.	2.
WATER PRESS.	PSI	60.	50.	60.	60.	60.
HYDROCARBONS	PPMC	99.	93.	119.	123.	96.
CARBON MONOXIDE	PPM	298.	508.	274.	222.	222.
NITRIC OXIDE	PPM	320.	275.	200.	205.	215.
NITROGEN OXIDES	PPM	350.	275.	228.	230.	240.
CARBON DIOXIDE	PCT	5.3	5.1	5.1	5.4	5.0
OXYGEN	PCT	13.5	16.1	11.6	15.8	15.1
SMOKE OPACITY	PCT	4.2	4.2	4.5	4.4	3.5
HC MASS	GM-HR	47.349	45.610	60.147	58.619	50.255
CO MASS	GM-HR	275.89	483.12	266.69	204.08	223.53
NOX MASS	GM-HR	557.52	496.37	450.12	419.09	516.01
BSHC	GM/BHP-HR	.4077	.3927	.5077	.4861	.4200
BSCO	GM/BHP-HR	2.3754	4.1595	2.2513	1.6923	1.8683
BSNO	GM/BHP-HR	4.8002	4.2736	3.7997	3.4753	4.3130

TABLE C-10. ENGINE TEST RESULTS, CUMMINS ENGINE, 1200 RPM, 15% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		181.	191.	227.	241.	255.
NOM. WATER PCT.		15.	15.	15	15.	15.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	508.	508.	508.	508.	508.
BAR. PRESS.	IN-HG	29.29	29.15	29.05	28.96	29.06
DRY BULB	DEG F	81.	74.	84.	93.	85.
WET BULB	DEG F	64.	68.	76.	79.	77.
REL. HUMIDITY	PCT	39.	74.	70.	54.	70.
CORR. BHP	HP	116.2	116.4	118.7	121.0	119.1
CORR. BMEP	PSI	44.8	44.9	45.8	46.7	46.0
FUEL FLOW	LB/HR	54.19	53.25	53.70	53.06	53.38
WATER FLOW	CC/MIN	79.6	82.8	82.8	81.2	82.8
CALC. VOL. %	PCT.	13.9	14.6	14.5	14.4	14.6
BSFC	LB/BHP-HR	.4664	.4575	.4524	.4384	.4483
AIR FLOW	LB/MIN	37.7	37.6	36.9	36.3	36.6
STOICH. F/A		.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0240	.0236	.0242	.0244	.0243
CALC. F/A		.0249	.0240	.0242	.0251	.0250
% DIFF.	PCT	3.74	1.55	-.26	2.80	2.66
COOLANT IN	DEG F	170.	173.	176.	174.	178.
COOLANT OUT	DEG F	180.	182.	184.	182.	185.
OIL SUMP	DEG F	195.	196.	198.	197.	199.
FUEL IN	DEG F	100.	97.	100.	103.	100.
FUEL RETURN	DEG F	150.	149.	147.	149.	148.
FUEL SUPPLY	DEG F	96.	99.	102.	109.	102.
FUEL COOLER	DEG F	98.	95.	95.	99.	97.
INTAKE AIR	DEG F	83.	75.	82.	94.	84.
TURB. INLET (L)	DEG F	617.	598.	606.	625.	615.
TURB. INLET (R)	DEG F	612.	617.	633.	618.	628.
COMP. OUT (L)	DEG F	114.	105.	112.	123.	114.
COMP. OUT (R)	DEG F	114.	105.	112.	123.	117.
CHARGE AIR (L)	DEG F	168.	168.	170.	171.	172.
CHARGE AIR (R)	DEG F	169.	169.	171.	172.	173.
EXH. STACK (R)	DEG F	561.	564.	577.	565.	574.
EXH. STACK (L)	DEG F	565.	547.	553.	571.	562.
WATER INLET	DEG F	86.	82.	87.	95.	88.
CELL AIR	DEG F	83.	76.	86.	95.	86.
EXHAUST 1R	DEG F	651.	658.	681.	663.	672.
EXHAUST 2R	DEG F	553.	559.	578.	561.	582.
EXHAUST 3R	DEG F	584.	590.	601.	589.	592.
EXHAUST 4R	DEG F	629.	637.	651.	639.	633.
EXHAUST 5R	DEG F	611.	610.	629.	606.	634.
EXHAUST 6R	DEG F	672.	663.	690.	665.	676.
EXHAUST 1L	DEG F	632.	613.	630.	654.	641.
EXHAUST 2L	DEG F	659.	619.	636.	672.	661.
EXHAUST 3L	DEG F	594.	583.	603.	604.	591.
EXHAUST 4L	DEG F	602.	587.	595.	602.	596.
EXHAUST 5L	DEG F	655.	634.	659.	677.	660.
EXHAUST 6L	DEG F	646.	627.	647.	653.	640.
OIL PRESSURE	PSI	65.	65.	64.	65.	64.
RAIL PRESSURE	PSI	15.2	15.5	17.0	17.0	18.0
BOOST (R)	PSI	1.8	1.8	1.8	1.5	1.8
BOOST (L)	PSI	2.8	2.5	2.5	2.7	2.2
INLET VAC. (R)	IN-H2O	3.7	3.8	4.2	4.6	5.3
EXH. PRESS. (R)	PSI	.1	.1	0.0	0.0	.1
EXH. PRESS. (L)	PSI	.1	.1	1.0	.1	.2
TURB. IN. (R)	IN-HG	2.5	2.5	2.5	2.5	2.5
TURB. IN. (L)	IN-HG	1.2	1.2	1.3	1.2	1.5
FUEL PRESS.	PSI	19.	22.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	2.	2.	0.
WATER PRESS.	PSI	60.	50.	60.	60.	0.
HYDROCARBONS	PPMC	125.	108.	124.	152.	105.
CARBON MONOXIDE	PPM	246.	571.	246.	239.	239.
NITRIC OXIDE	PPM	320.	263.	205.	202.	210.
NITROGEN OXIDES	PPM	355.	300	234.	232.	335.
CARBON DIOXIDE	PCT	5.3	5.1	5.1	5.3	5.3
OXYGEN	PCT	13.4	16.1	9.6	15.4	15.4
SMOKE OPACITY	PCT	3.4	3.9	4.0	4.6	2.2
HC MASS	GM-HR	60.609	53.197	61.402	71.818	50.092
CO MASS	GM-HR	230.08	544.39	234.59	217.19	219.32
NOX MASS	GM-HR	579.26	568.46	476.76	444.63	467.22
BSHC	GM/BHP-HR	.5216	.4570	.5173	.5934	.4206
BSCO	GM/BHP-HR	1.9800	4.6764	1.9764	1.7944	1.8417
BSNO	GM/BHP-HR	4.9849	4.8832	4.0167	3.6735	3.9233

TABLE C-11. ENGINE TEST RESULTS, CUMMINS ENGINE, 1200 RPM, 20% WATER

DYNAMOMETER CONSTANT: 3000   API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		182.	192.	228.	242.	256.
NOM. WATER PCT.		20.	20.	20.	20.	20.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	508.	508.	508.	508.	508.
BAR. PRESS.	IN-HG	29.28	29.16	29.06	28.96	29.12
DRY BULB	DEG F	81.	77.	84.	93.	82.
WET BULB	DEG F	64.	70.	76.	79.	75.
REL. HUMIDITY	PCT	39.	71.	70.	54.	72.
CORR. BHP	HP	116.5	116.7	119.3	121.2	118.2
CORR. BMEP	PSI	45.0	45.0	46.0	46.8	45.6
FUEL FLOW	LB/HR	53.71	53.04	53.92	53.80	54.77
WATER FLOW	CC/MIN	114.0	111.0	114.0	114.0	111.0
CALC. VOL. %	PCT.	18.9	18.7	18.9	18.9	18.3
BSFC	LB/BHP-HR	.4609	.4546	.4521	.4439	.4635
AIR FLOW	LB/MIN	37.5	37.4	36.7	36.2	36.7
STOICH. F/A		.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0239	.0236	.0245	.0248	.0249
CALC. F/A		.0249	.0243	.0250	.0250	.0250
% DIFF.	PCT	4.36	2.82	1.76	.82	.35
COOLANT IN	DEG F	170.	177.	177.	174.	178.
COOLANT OUT	DEG F	180.	185.	185.	182.	185.
OIL SUMP	DEG F	195.	198.	199.	197.	198.
FUEL IN	DEG F	101.	98.	101.	105.	99.
FUEL RETURN	DEG F	150.	151.	148.	149.	147.
FUEL SUPPLY	DEG F	96.	98.	106.	111.	101.
FUEL COOLER	DEG F	99.	97.	96.	100.	95.
INTAKE AIR	DEG F	85.	76.	86.	95.	81.
TURB. INLET (L)	DEG F	601.	588.	596.	608.	596.
TURB. INLET (R)	DEG F	603.	611.	625.	606.	611.
COMP. OUT (L)	DEG F	114.	107.	115.	123.	110.
COMP. OUT (R)	DEG F	114.	107.	115.	124.	114.
CHARGE AIR (L)	DEG F	168.	171.	172.	172.	171.
CHARGE AIR (R)	DEG F	169.	172.	173.	173.	172.
EXH. STACK (R)	DEG F	552.	558.	571.	556.	559.
EXH. STACK (L)	DEG F	551.	538.	546.	557.	546.
WATER INLET	DEG F	85.	81.	88.	95.	88.
CELL AIR	DEG F	84.	77.	86.	96.	83.
EXHAUST 1R	DEG F	634.	644.	665.	648.	655.
EXHAUST 2R	DEG F	542.	555.	567.	657.	573.
EXHAUST 3R	DEG F	580.	588.	597.	584.	583.
EXHAUST 4R	DEG F	612.	622.	636.	619.	617.
EXHAUST 5R	DEG F	601.	602.	632.	599.	622.
EXHAUST 6R	DEG F	655.	647.	675.	648.	656.
EXHAUST 1L	DEG F	614.	609.	609.	625.	618.
EXHAUST 2L	DEG F	637.	614.	619.	654.	640.
EXHAUST 3L	DEG F	577.	572.	585.	586.	570.
EXHAUST 4L	DEG F	586.	581.	589.	588.	580.
EXHAUST 5L	DEG F	564.	613.	634.	656.	639.
EXHAUST 6L	DEG F	615.	604.	620.	628.	615.
OIL PRESSURE	PSI	65.	63.	64.	65.	64.
RAIL PRESSURE	PSI	15.5	15.8	20.0	18.0	19.0
BOOST (R)	PSI	1.6	1.8	1.6	1.5	1.5
BOOST (L)	PSI	2.7	2.5	2.5	2.5	2.4
INLET VAC. (R)	IN-H2O	3.7	3.8	4.2	4.6	5.3
EXH. PRESS. (R)	PSI	.1	.1	0.0	0.0	.1
EXH. PRESS. (L)	PSI	.1	.1	.1	.1	.2
TURB. IN. (R)	IN-HG	2.5	2.5	2.5	2.5	2.5
TURB. IN. (L)	IN-HG	1.2	1.2	1.2	1.2	1.3
FUEL PRESS.	PSI	18.	22.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	2.	2.	2.
WATER PRESS.	PSI	60.	50.	60.	60.	60.
HYDROCARBONS	PPMC	175.	149.	149.	146.	95.
CARBON MONOXIDE	PPM	263.	613.	229.	263.	267.
NITRIC OXIDE	PPM	330.	275.	211.	215.	220.
NITROGEN OXIDES	PPM	360.	313.	248.	249.	250.
CARBON DIOXIDE	PCT	5.3	5.1	5.3	5.3	5.3
OXYGEN	PCT	13.6	16.0	9.3	15.4	15.6
SMOKE OPACITY	PCT	2.7	3.6	4.0	3.9	1.5
HC MASS	GM-HR	84.052	72.323	71.784	70.145	46.490
CO MASS	GM-HR	243.65	574.23	212.32	242.91	250.79
NOX MASS	GM-HR	607.14	611.45	514.93	509.42	520.16
BSHC	GM/BHP-HR	.7212	.6198	.6019	.5788	.3934
BSCO	GM/BHP-HR	2.0906	4.9214	1.7802	2.0043	2.1223
BSNO	GM/BHP-HR	5.2097	5.2405	4.3176	4.2035	4.4018

TABLE C-12. ENGINE TEST RESULTS, CUMMINS ENGINE, 1200 RPM, 25% WATER

DYNAMOMETER CONSTANT: 3000   API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		193.	229.	243.	257.
NOM. WATER PCT.		25.	25.	25.	25.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	508.	508	508.	508.
BAR. PRESS.	IN-HG	29.17	29.04	28.95	29.11
DRY BULB	DEG F	77.	88.	94.	82.
WET BULB	DEG F	70.	76.	80.	73.
REL. HUMIDITY	PCT	71.	58.	55.	65.
CORR. BHP	HP	117.1	119.5	121.5	117.9
CORR. BMEP	PSI	45.2	46.1	46.9	45.5
FUEL FLOW	LB/HR	53.33	53.66	53.75	53.57
WATER FLOW	CC/MIN	143.8	159.0	159.0	159.0
CALC. VOL. %	PCT.	22.9	24.6	24.5	24.6
BSFC	LB/BHP-HR	.4555	.4491	.4423	.4544
AIR FLOW	LB/MIN	37.2	36.5	36.0	36.5
STOICH. F/A		.0691	.0691	.0691	.0691
MEAS. F/A		.0239	.0245	.0249	.0244
CALC. F/A		.0248	.0240	.0252	.0236
% DIFF.	PCT	3.84	-1.99	1.18	-3.42
COOLANT IN	DEG F	178.	177.	176.	178.
COOLANT OUT	DEG F	185.	185.	184.	186.
OIL SUMP	DEG F	198.	198.	197.	190.
FUEL IN	DEG F	97.	102.	105.	100.
FUEL RETURN	DEG F	149.	147.	149.	147.
FUEL SUPPLY	DEG F	100.	107.	112.	102.
FUEL COOLER	DEG F	94.	98.	102.	96.
INTAKE AIR	DEG F	79.	88.	96.	81.
TURB. INLET (L)	DEG F	582.	578.	595.	583.
TURB. INLET (R)	DEG F	605.	612.	598.	603.
COMP. OUT (L)	DEG F	109.	117.	124.	110.
COMP. OUT (R)	DEG F	110.	116.	125.	117.
CHARGE AIR (L)	DEG F	171.	172.	172.	171.
CHARGE AIR (R)	DEG F	172.	173.	173.	173.
EXH. STACK (R)	DEG F	552.	559.	549.	552.
EXH. STACK (L)	DEG F	532.	531.	547.	536.
WATER INLET	DEG F	84.	89.	95.	88.
CELL AIR	DEG F	78.	90.	98.	82.
EXHAUST 1R	DEG F	630.	645.	634.	637.
EXHAUST 2R	DEG F	552.	558.	548.	563.
EXHAUST 3R	DEG F	582.	591.	580.	578.
EXHAUST 4R	DEG F	604.	611.	602.	600.
EXHAUST 5R	DEG F	593.	615.	593.	607.
EXHAUST 6R	DEG F	626.	650.	630.	631.
EXHAUST 1L	DEG F	594.	582.	603.	594.
EXHAUST 2L	DEG F	605.	603.	634.	622.
EXHAUST 3L	DEG F	563.	569.	572.	558.
EXHAUST 4L	DEG F	571.	571.	576.	566.
EXHAUST 5L	DEG F	570.	610.	632.	615.
EXHAUST 6L	DEG F	578.	581.	602.	590.
OIL PRESSURE	PSI	64.	64.	65.	64.
RAIL PRESSURE	PSI	20.0	20.0	20.0	20.0
BOOST (R)	PSI	1.6	1.5	1.5	1.5
BOOST (L)	PSI	2.5	2.5	2.4	2.1
INLET VAC. (R)	IN-H2O	3.8	4.2	4.6	5.2
EXH. PRESS. (R)	PSI	.1	0.0	0.0	.1
EXH. PRESS. (L)	PSI	.1	.1	.1	.2
TURB. IN. (R)	IN-HG	2.5	2.4	2.5	2.5
TURB. IN. (L)	IN-HG	1.2	1.2	1.2	1.1
FUEL PRESS.	PSI	22.	20.	20	20
EMULSION PRESS.	PSI	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2	2	2.
WATER PRESS.	PSI	50.	60.	60.	60
HYDROCARBONS	PPMC	250.	193	211	132.
CARBON MONOXIDE	PPM	749.	316.	417.	383.
NITRIC OXIDE	PPM	275.	216.	210.	215.
NITROGEN OXIDES	PPM	325	250.	250	250.
CARBON DIOXIDE	PCT	5.2	5.1	5.3	5.0
OXYGEN	PCT	16.0	9.5	15.9	15.5
SMOKE OPACITY	PCT	2.9	3.1	3.5	1.0
HC MASS	GM-HR	120.00	96.372	100.63	66.775
CO MASS	GM-HR	690.83	303.46	381.53	372.81
NOX MASS	GM-HR	657.90	555.93	556.28	557.48
BSHC	GM/BHP-HR	1.0248	.8067	.8281	.5666
BSCO	GM/BHP-HR	5.8998	2.5400	3.1394	3.1626
BSNO	GM/BHP-HR	5.6186	4.6525	4.5773	4.7291

TABLE C-13. ENGINE TEST RESULTS, CUMMINS ENGINE, 1800 RPM, BASELINE

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		171.	177.	183.	188.	195.	201.	216.
NOM. WATER PCT.		0.	0.	0.	0.	0.	0.	0.
ENGINE SPEED	RPM	1800.	1800.	1800.	1200.	1800.	1800.	1800.
OBS. TORQUE	LB-FT	1257.	1257.	1257.	508.	1257.	1257	1257.
BAR. PRESS.	IN-HG	29.29	29.16	28.96	29.11	29.22	29.26	29.10
DRY BULB	DEG F	82.	91.	81.	73.	79.	78.	89
WET BULB	DEG F	73.	73.	76.	68.	74.	72.	76.
REL. HUMIDITY	PCT	65.	42.	80.	78.	79.	75.	55.
CORR. BHP	HP	436.2	441.7	443.9	116.2	436.1	433.9	444.3
CORR. BMEP	PSI	112.2	113.7	114.2	44.8	112.2	111.6	114.3
FUEL FLOW	LB/HR	181.93	179.14	180.80	55.30	179.19	180.09	177.08
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BSFC	LB/BHP-HR	.4171	.4056	.4073	.4761	.4109	.4151	.3986
AIR FLOW	LB/MIN	83.5	82.6	83.7	38.0	85.0	84.5	81.4
STOICH. F/A		.0691	.0691	.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0363	.0361	.0360	.0242	.0351	.0355	.0363
CALC. F/A		.0335	.0324	.0341	.0248	.0347	.0348	.0342
% DIFF.	PCT	-7.63	-10.37	-5.24	2.37	-1.15	-1.88	-5.58
COOLANT IN	DEG F	177.	178.	176.	172.	173.	177.	173.
COOLANT OUT	DEG F	188.	189.	186.	181.	184.	188.	186.
OIL SUMP	DEG F	221.	222.	218.	194.	217.	219.	217.
FUEL IN	DEG F	105.	104.	107.	92.	105.	103.	110.
FUEL RETURN	DEG F	153.	154.	155.	149.	152.	152.	153.
FUEL SUPPLY	DEG F	89.	92.	92.	94.	90	89.	96.
FUEL COOLER	DEG F	106.	106.	109.	90.	105.	105.	109.
INTAKE AIR	DEG F	83.	92.	84.	72.	79.	78.	91.
TURB. INLET (L)	DEG F	965.	969.	949.	629.	937.	942.	959.
TURB. INLET (R)	DEG F	927.	977.	960.	657.	953.	951.	965.
COMP. OUT (L)	DEG F	231.	240.	232.	106.	225.	224.	234.
COMP. OUT (R)	DEG F	228.	238.	230.	105.	224.	223.	232
CHARGE AIR (L)	DEG F	194.	197.	192.	168.	189.	191.	192.
CHARGE AIR (R)	DEG F	194.	197.	194.	169.	190.	192.	192.
EXH. STACK (R)	DEG F	816.	824.	805.	599.	800.	800.	813.
EXH. STACK (L)	DEG F	806.	813.	792.	574	780.	787.	801.
WATER INLET	DEG F	88.	100.	89.	75.	82.	88.	95.
CELL AIR	DEG F	86.	95.	84.	76.	80.	80.	92.
EXHAUST 1R	DEG F	956.	965.	945.	713.	935.	936.	949.
EXHAUST 2R	DEG F	928.	936.	931.	598.	908.	911.	924.
EXHAUST 3R	DEG F	938.	947.	919.	600.	925.	921.	935.
EXHAUST 4R	DEG F	914.	925.	904.	669.	900.	898.	911.
EXHAUST 5R	DEG F	935.	943.	926.	654.	915.	915.	929.
EXHAUST 6R	DEG F	958.	963.	951.	711.	943.	937.	955.
EXHAUST 1L	DEG F	1005.	1019.	994.	655.	980.	981.	993.
EXHAUST 2L	DEG F	961.	973.	955.	678.	940.	940.	958.
EXHAUST 3L	DEG F	916.	929.	907.	601.	898.	901.	917.
EXHAUST 4L	DEG F	929.	942.	921.	618.	911.	908.	928.
EXHAUST 5L	DEG F	932.	944.	920.	639.	912.	915.	923.
EXHAUST 6L	DEG F	955.	959.	933.	679.	926.	925.	951.
OIL PRESSURE	PSI	76.	76.	76.	66.	76.	76.	76.
RAIL PRESSURE	PSI	75.0	75.0	75.0	149.0	75.0	75.0	74.0
BOOST (R)	PSI	11.0	10.9	11.2	1.8	11.2	11.1	10.9
BOOST (L)	PSI	10.5	11.3	10.5	2.5	10.8	11.5	10.2
INLET VAC. (R)	IN-H2O	12.3	12.7	13.0	3.8	13.6	13.9	13.7
EXH. PRESS. (R)	PSI	.3	.3	.3	.1	.1	.1	.2
EXH. PRESS. (L)	PSI	.6	.6	.5	.1	.5	.5	.5
TURB. IN. (R)	IN-HG	11.0	11.0	11.0	2.5	11.2	11.1	11.0
TURB. IN. (L)	IN-HG	10.0	10.0	10.0	1.4	10.0	10.0	0.0
FUEL PRESS.	PSI	22.	20.	20.	21.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	2.	2.	2.	2.	2.
WATER PRESS.	PSI	0.	0.	0.	0.	0.	0.	0.
HYDROCARBONS	PPMC	100.	40.	130.	54.	78.	70.	82.
CARBON MONOXIDE	PPM	306.	163.	635.	212.	281.	550.	125.
NITRIC OXIDE	PPM	900.	950.	870.	288.	850.	850.	288.
NITROGEN OXIDES	PPM	863	950	880	313	838.	850.	750.
CARBON DIOXIDE	PCT	7.2	7.0	7.3	5.3	7.5	7.5	7.4
OXYGEN	PCT	10.5	10.3	11.5	15.8	12.2	12.3	15.0
SMOKE OPACITY	PCT	0.0	0.0	6.9	8.6	5.4	5.9	6.0
HC MASS	GM-HR	121.64	49.507	154.76	26.649	89.849	81.249	95.154
CO MASS	GM-HR	704.86	384.81	1431.4	203.00	615.43	1206.3	274.58
NOX MASS	GM-HR	3527.4	3789.1	3719.8	535.94	3371.8	3339.2	2949.6
BSHC	GM/BHP-HR	.2789	.1121	.3486	.2294	.2060	.1873	.2142
BSCO	GM/BHP-HR	1.6161	.8712	3.2248	1.7475	1.4113	2.7802	.6181
BSNO	GM/BHP-HR	8.0876	8.5787	8.3803	4.6137	7.7323	7.6960	6.6393

TABLE C-13. ENGINE TEST RESULTS, CUMMINS ENGINE, 1800 RPM, BASELINE (CONT'D)

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		217	223.	231.	237.	245	251
NOM. WATER PCT.		0.	0.	0.	0	0	0
ENGINE SPEED	RPM	1800.	1800.	1800.	1800	1800	1800
OBS. TORQUE	LB-FT	1257.	1257.	1257	1257.	1257.	1257
BAR. PRESS.	IN-HG	29.19	29.24	28.95	29.00	28.94	28.91
DRY BULB	DEG F	80.	89.	83	92.	88.	90
WET BULB	DEG F	73.	76.	75.	80.	76	78
REL. HUMIDITY	PCT	72.	55	69.	60	58	59
CORR. BHP	HP	436.3	440.9	442.5	448.6	445.3	447.3
CORR. BMEP	PSI	112.3	113.5	113.9	115.4	114.6	115.1
FUEL FLOW	LB/HR	179.60	179.37	180.41	180.68	182.23	181.73
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	0.0	0.0
BSFC	LB/BHP-HR	.4116	.4068	.4077	.4028	.4093	.4063
AIR FLOW	LB/MIN	83.7	83.1	81.9	81.2	82.1	80.6
STOICH. F/A		.0691	.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0358	.0360	.0367	.0371	.0376	.0376
CALC. F/A		.0343	.0350	.0336	.0354	.0358	.0347
% DIFF.	PCT	-4.12	-2.85	-8.39	-4.51	-3.19	-7.62
COOLANT IN	DEG F	161	161.	175	174	172	170.
COOLANT OUT	DEG F	181.	180	187.	185.	184	184
OIL SUMP	DEG F	214.	216.	219.	218	220.	218
FUEL IN	DEG F	106.	110.	109	109	110.	109
FUEL RETURN	DEG F	148.	152.	153	155	154	154.
FUEL SUPPLY	DEG F	90	102.	92	96	95	96
FUEL COOLER	DEG F	106.	109.	110.	110	111.	110.
INTAKE AIR	DEG F	80	89.	83	92.	83	89.
TURB. INLET (L)	DEG F	941.	958	961	966.	968.	968.
TURB. INLET (R)	DEG F	949	963	964	975	977	977.
COMP. OUT (L)	DEG F	225	234.	229	238	235.	234
COMP. OUT (R)	DEG F	223.	232.	227.	236.	232.	232.
CHARGE AIR (L)	DEG F	185.	188	191	193.	191	190.
CHARGE AIR (R)	DEG F	186.	188	192	193.	191.	191.
EXH. STACK (R)	DEG F	796	812	808	822.	822	823
EXH. STACK (L)	DEG F	784	802.	800.	810	810.	812.
WATER INLET	DEG F	84.	99.	87	99.	93	102
CELL AIR	DEG F	81.	90.	86.	95.	89	92.
EXHAUST 1R	DEG F	936.	953.	941.	958	955.	958
EXHAUST 2R	DEG F	912	926.	920.	935	928.	930.
EXHAUST 3R	DEG F	920.	931.	931.	944	943	940.
EXHAUST 4R	DEG F	894	910	911	921.	918	921
EXHAUST 5R	DEG F	908.	925.	924.	934	937.	932.
EXHAUST 6R	DEG F	937.	958	952.	961.	964	957.
EXHAUST 1L	DEG F	973	994.	981	999.	996.	1002.
EXHAUST 2L	DEG F	944	955.	952.	966.	963	965.
EXHAUST 3L	DEG F	905.	920.	910.	926.	922	923.
EXHAUST 4L	DEG F	913.	921.	926	931.	935.	928.
EXHAUST 5L	DEG F	906.	920	919.	930	930.	928
EXHAUST 6L	DEG F	923.	949.	945.	956.	953.	956
OIL PRESSURE	PSI	78.	77.	76.	76.	76.	77.
RAIL PRESSURE	PSI	75.0	75.0	75.0	75.0	75.0	75.0
BOOST (R)	PSI	11.2	10.8	11.2	10.8	11.0	10.8
BOOST (L)	PSI	10.2	10.5	10.5	10.2	10.8	10.2
INLET VAC. (R)	IN-H2O	14.1	14.2	14.7	14.9	15.9	16.5
EXH. PRESS. (R)	PSI	.2	.2	.1	.2	.1	.2
EXH. PRESS. (L)	PSI	.6	.5	.5	.5	.6	.5
TURB. IN. (R)	IN-HG	11.0	11.0	11.0	11.0	10.0	11.0
TURB. IN. (L)	IN-HG	10.0	10.0	10.0	9.8	10.0	9.8
FUEL PRESS.	PSI	20.	20.	20.	20	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100	100
FUEL SUPPLY	PSI	3.	2.	2.	2.	2	2.
WATER PRESS.	PSI	0.	0.	0	0.	0.	0.
HYDROCARBONS	PPMC	61.	55	50.	60.	94.	29.
CARBON MONOXIDE	PPM	246.	253	246.	281.	250	284.
NITRIC OXIDE	PPM	650.	625	605	675.	573	565.
NITROGEN OXIDES	PPM	738.	638.	623.	698.	598	580.
CARBON DIOXIDE	PCT	7.4	7.6	7.3	7.6	7.7	7.5
OXYGEN	PCT	14.0	11.9	12.7	12.8	10.3	12.3
SMOKE OPACITY	PCT	5.0	7.2	4.7	8.2	6.0	5.7
HC MASS	GM-HR	71.696	63.377	60.193	69.172	107.48	34.118
CO MASS	GM-HR	547.33	551.08	561.61	607.75	538.52	632.33
NOX MASS	GM-HR	2949.4	2483.0	2588.0	2842.1	2322.1	2372.5
BSHC	GM/BHP-HR	.1643	.1437	.1360	.1542	.2414	.0763
BSCO	GM/BHP-HR	1.2544	1.2498	1.2692	1.3547	1.2094	1.4137
BSNO	GM/BHP-HR	6.7594	5.6311	5.8488	6.3354	5.2151	5.3042

TABLE C-14. ENGINE TEST RESULTS, CUMMINS ENGINE, 1800 RPM, 5% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		172.	184.	196.	218.	232.	246
NOM. WATER PCT.		5.	5.	5.	5.	5.	5.
ENGINE SPEED	RPM	1800.	1800.	1800.	1800.	1800.	1800.
OBS. TORQUE	LB-FT	1257.	1257.	1257.	1257.	1257.	1257.
BAR. PRESS.	IN-HG	29.27	28.95	29.23	29.21	28.96	28.95
DRY BULB	DEG F	82.	94.	79.	80.	83.	89.
WET BULB	DEG F	73.	82.	74.	73.	75.	76.
REL. HUMIDITY	PCT	65.	60.	79.	72.	69.	55.
CORR. BHP	HP	437.6	453.4	437.0	437.2	442.9	446.6
CORR. BMEP	PSI	112.6	116.7	112.5	112.5	114.0	114.9
FUEL FLOW	LB/HR	179.89	168.98	178.13	178.26	179.46	181.31
WATER FLOW	CC/MIN	82.8	82.8	82.8	82.8	82.8	82.8
CALC. VOL. %	PCT.	4.8	5.1	4.9	4.9	4.8	4.8
BSFC	LB/BHP-HR	.4111	.3727	.4076	.4078	.4052	.4060
AIR FLOW	LB/MIN	82.9	80.8	83.5	83.2	81.7	79.7
STOICH. F/A		.0691	.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0362	.0348	.0355	.0357	.0366	.0379
CALC. F/A		.0326	.0345	.0343	.0343	.0336	.0358
% DIFF.	PCT	-9.98	-.98	-3.49	-4.00	-8.19	-5.61
COOLANT IN	DEG F	178.	1172.	172.	163.	176.	174.
COOLANT OUT	DEG F	188.	184.	184.	182.	187.	186.
OIL SUMP	DEG F	222.	218.	217.	216.	219.	220.
FUEL IN	DEG F	106.	111.	107.	107.	109.	112.
FUEL RETURN	DEG F	153.	156.	152.	149.	93.	155.
FUEL SUPPLY	DEG F	91.	98.	92.	92.	153.	97.
FUEL COOLER	DEG F	109.	113.	109.	11.	110.	111.
INTAKE AIR	DEG F	85.	97.	81.	82.	84.	91.
TURB. INLET (L)	DEG F	952.	958.	934.	937.	946.	962.
TURB. INLET (R)	DEG F	929.	965.	943.	944.	952.	968.
COMP. OUT (L)	DEG F	231.	240.	225.	225.	227.	235.
COMP. OUT (R)	DEG F	229.	240.	224.	223.	225.	233.
CHARGE AIR (L)	DEG F	195.	193.	189.	186.	190.	192.
CHARGE AIR (R)	DEG F	195.	194.	190.	187.	191.	193.
EXH. STACK (R)	DEG F	808.	812.	794.	793.	803.	817.
EXH. STACK (L)	DEG F	799.	803.	780.	782.	791.	807.
WATER INLET	DEG F	83.	89.	84.	84.	89.	96.
CELL AIR	DEG F	88.	94.	82.	83.	86.	92.
EXHAUST 1R	DEG F	937.	947.	925.	929.	934.	946.
EXHAUST 2R	DEG F	914.	920.	899.	905.	913.	921.
EXHAUST 3R	DEG F	928.	939.	915.	915.	925.	935.
EXHAUST 4R	DEG F	905.	911.	894.	894.	903.	916.
EXHAUST 5R	DEG F	920.	926.	906.	899.	910.	928.
EXHAUST 6R	DEG F	940.	949.	931.	929.	937.	948.
EXHAUST 1L	DEG F	995.	1001.	915.	971.	977.	995.
EXHAUST 2L	DEG F	952.	957.	935.	936.	943.	958.
EXHAUST 3L	DEG F	909.	915.	894.	900.	906.	922.
EXHAUST 4L	DEG F	921.	925.	906.	899.	912.	923.
EXHAUST 5L	DEG F	921.	923.	907.	903.	913.	927.
EXHAUST 6L	DEG F	934.	945.	919.	927.	938.	948.
OIL PRESSURE	PSI	75.	76.	76.	77.	76.	76.
RAIL PRESSURE	PSI	78.0	89.0	78.0	80.0	78.0	80.0
BOOST (R)	PSI	10.9	10.7	11.0	11.0	10.8	10.6
BOOST (L)	PSI	10.7	10.9	10.8	10.5	10.5	10.8
INLET VAC. (R)	IN-H2O	12.3	13.1	13.6	13.8	14.5	15.8
EXH. PRESS. (R)	PSI	.3	.3	.1	.2	.1	.1
EXH. PRESS. (L)	PSI	.5	.5	.5	.6	.5	.5
TURB. IN. (R)	IN-HG	11.0	11.0	11.0	11.0	11.0	10.5
TURB. IN. (L)	IN-HG	9.8	9.8	9.8	10.0	9.8	9.5
FUEL PRESS.	PSI	22.	18.	20.	20.	20.	20.
EMULSION PRESS.	PSI	100.	150.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	2.	3.	2.	2.
WATER PRESS.	PSI	60.	50.	50.	50.	65.	0.
HYDROCARBONS	PPMC	110.	150.	95.	50.	55.	90.
CARBON MONOXIDE	PPM	263.	592.	246.	229.	219.	219.
NITRIC OXIDE	PPM	925.	870.	850.	742.	625.	640.
NITROGEN OXIDES	PPM	875.	915.	875.	632.	645.	648.
CARBON DIOXIDE	PCT	7.0	7.4	7.4	7.4	7.3	7.7
OXYGEN	PCT	10.0	10.5	12.5	13.4	13.2	9.9
SMOKE OPACITY	PCT	0.0	5.1	4.2	4.3	3.5	4.2
HC MASS	GM-HR	136.23	165.36	110.81	58.392	65.327	102.49
CO MASS	GM-HR	619.35	1231.8	542.95	505.92	497.47	470.61
NOX MASS	GM-HR	3790.3	3869.4	3681.6	2606.0	2774.6	2584.7
BSHC	GM/BHP-HR	.3113	.3647	.2535	.1336	.1475	.2295
BSCO	GM/BHP-HR	1.4154	2.7169	1.2423	1.1573	1.1232	1.0537
BSNO	GM/BHP-HR	8.6618	8.5346	8.4237	5.9613	6.2647	5.7870

TABLE C-15. ENGINE TEST RESULTS, CUMMINS ENGINE, 1800 RPM, 10% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		173.	185.	197.	219.	233.	247.
NOM. WATER PCT.		10.	10.	10.	10.	10.	10.
ENGINE SPEED	RPM	1800.	1800.	1800.	1800	1800.	1800.
OBS. TORQUE	LB-FT	1257.	1257	1257.	1257.	1257.	1257.
BAR. PRESS	IN-HG	29.25	28.92	29.23	29.23	28.98	28.95
DRY BULB	DEG F	82.	93	79	82.	83.	89
WET BULB	DEG F	73.	80.	74.	73.	75.	76.
REL. HUMIDITY	PCT	65.	57.	79.	65.	69.	55.
CORR. BHP	HP	438.5	450.9	437.0	437.1	443.1	447.8
CORR. BMEP	PSI	112.8	116.0	112.5	112.5	114.0	115.2
FUEL FLOW	LB/HR	179.18	179.68	177.73	178.31	177.60	179.91
WATER FLOW	CC/MIN	175.1	171.8	175.1	171.8	171.8	175.1
CALC. VOL. %	PCT	9.7	9.5	9.8	9.6	9.6	9.6
BSFC	LB/BHP-HR	.4087	.3985	.4067	.4080	.4008	.4018
AIR FLOW	LB/MIN	81.7	80.8	82.6	82.2	80.7	79.1
STOICH. F/A		.0691	.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0365	.0370	.0358	.0362	.0367	.0379
CALC. F/A		.0332	.0349	.0348	.0343	.0346	.0369
% DIFF.	PCT	-9.21	-5.76	-2.85	-5.24	-5.67	-2.71
COOLANT IN	DEG F	178.	173.	172.	163.	176.	175.
COOLANT OUT	DEG F	188.	185.	184.	182.	188.	186.
OIL SUMP	DEG F	222.	218.	217.	216.	219.	219.
FUEL IN	DEG F	109.	114.	109.	109.	111.	114.
FUEL RETURN	DEG F	153.	156.	152.	149.	153.	155.
FUEL SUPPLY	DEG F	92.	98.	92.	92.	94.	99.
FUEL COOLER	DEG F	110.	114.	112.	110.	113.	115.
INTAKE AIR	DEG F	86.	94.	81.	83.	85.	93.
TURB. INLET (L)	DEG F	935.	940.	919.	924.	938.	950.
TURB. INLET (R)	DEG F	925.	949.	928.	932.	945.	959.
COMP. OUT (L)	DEG F	228.	235.	222.	224.	227.	235.
COMP. OUT (R)	DEG F	226.	234.	220	222.	225.	233.
CHARGE AIR (L)	DEG F	193.	192.	188.	186.	190.	192.
CHARGE AIR (R)	DEG F	193.	192.	188.	186.	191.	192.
EXH. STACK (R)	DEG F	795.	801.	783.	785.	798.	810.
EXH. STACK (L)	DEG F	785.	789.	769.	770.	786.	800.
WATER INLET	DEG F	97.	106.	96.	97.	98.	107.
CELL AIR	DEG F	88.	96.	81.	84.	87.	94.
EXHAUST 1R	DEG F	924.	930.	911.	917.	922.	940.
EXHAUST 2R	DEG F	902.	906.	889.	901.	905.	918.
EXHAUST 3R	DEG F	916.	921.	904.	910.	913.	928.
EXHAUST 4R	DEG F	891.	896.	879.	887.	892.	905.
EXHAUST 5R	DEG F	906.	914.	895.	896.	903.	920.
EXHAUST 6R	DEG F	927.	933.	916.	916.	920.	925.
EXHAUST 1L	DEG F	982.	985.	963.	958.	963.	983.
EXHAUST 2L	DEG F	937.	941.	922.	922.	930.	945.
EXHAUST 3L	DEG F	901.	905.	885.	898.	900.	914.
EXHAUST 4L	DEG F	910.	911.	893.	896.	906.	917.
EXHAUST 5L	DEG F	906.	911.	897.	896.	905.	920.
EXHAUST 6L	DEG F	925.	932.	908.	919.	923.	947.
OIL PRESSURE	PSI	76.	76.	76.	77.	76.	76.
RAIL PRESSURE	PSI	84.0	83.0	83.0	85.0	83.0	85.0
BOOST (R)	PSI	10.5	10.5	10.6	10.5	10.7	10.2
BOOST (L)	PSI	10.8	11.0	10.8	10.5	10.5	11.0
INLET VAC. (R)	IN-H2O	12.2	13.0	13.4	13.7	14.4	15.7
EXH. PRESS. (R)	PSI	.3	.2	.2	.1	.2	.1
EXH. PRESS. (L)	PSI	.5	.5	.5	.5	.5	.5
TURB. IN. (R)	IN-HG	10.8	10.8	11.0	10.8	10.5	10.5
TURB. IN. (L)	IN-HG	9.5	9.5	9.8	9.8	9.5	9.5
FUEL PRESS.	PSI	22.	22.	20.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	2.	3.	2.	2.
WATER PRESS.	PSI	60.	50.	50.	50.	65.	65
HYDROCARBONS	PPMC	38.	166.	91.	58.	54.	70.
CARBON MONOXIDE	PPM	476.	592.	488.	212.	193.	202.
NITRIC OXIDE	PPM	938.	930.	888	775.	663.	683.
NITROGEN OXIDES	PPM	900.	940.	900.	630.	695.	683.
CARBON DIOXIDE	PCT	7.1	7.5	7.5	7.4	7.5	8.0
OXYGEN	PCT	10.5	10.7	12.0	14.0	12.8	11.8
SMOKE OPACITY	PCT	0.0	4.5	3.3	3.4	3.0	3.4
HC MASS	GM-HR	46.217	192.62	104.78	67.210	61.831	76.989
CO MASS	GM-HR	1093.0	1293.9	1057.5	468.53	419.70	418.81
NOX MASS	GM-HR	3978.3	4194.5	3892.7	2678.2	2998.4	2744.6
BSHC	GM/BHP-HR	.1054	.4272	.2397	.1538	.1395	.1719
BSCO	GM/BHP-HR	2.4929	2.8698	2.4197	1.0720	.9471	.9353
BSNO	GM/BHP-HR	9.0734	9.3034	8.9068	6.1276	6.7662	6.1294

TABLE C-16. ENGINE TEST RESULTS, CUMMINS ENGINE, 1800 RPM, 15% WATER

DYNAMOMETER CONSTANT: 3000   API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		174.	186.	198.	220.	234.	248.
NOM. WATER PCT.		15.	15.	15.	15.	15.	15.
ENGINE SPEED	RPM	1800.	1800.	1800.	1800.	1800.	1800.
OBS. TORQUE	LB-FT	1257.	1257.	1257.	1257.	1257.	1257.
BAR. PRESS.	IN-HG	29.22	28.90	29.24	29.25	29.00	28.96
DRY BULB	DEG F	89.	100.	82.	86.	87.	95.
WET BULB	DEG F	73.	94.	76.	76.	77.	77.
REL. HUMIDITY	PCT	47.	80.	76.	63.	64.	44.
CORR. BHP	HP	439.4	462.6	438.2	440.2	444.0	448.9
CORR. BMEP	PSI	113.1	119.0	112.8	113.3	114.2	115.5
FUEL FLOW	LB/HR	178.39	178.32	176.90	176.82	177.37	179.00
WATER FLOW	CC/MIN	284.9	288.5	288.5	288.5	277.7	284.9
CALC. VOL. %	PCT	14.9	15.0	15.2	15.2	14.6	14.8
BSFC	LB/BHP-HR	.4060	.3855	.4037	.4017	.3995	.3987
AIR FLOW	LB/MIN	81.0	79.3	81.4	80.2	79.5	77.6
STOICH. F/A		.0691	.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0367	.0375	.0362	.0368	.0372	.0384
CALC. F/A		.0332	.0353	.0348	.0349	.0349	.0372
% DIFF.	PCT	-9.50	-5.76	-3.83	-5.00	-6.09	-3.19
COOLANT IN	DEG F	178.	174.	172.	174.	175.	174.
COOLANT OUT	DEG F	189.	185.	184.	186.	186.	185.
OIL SUMP	DEG F	222.	219.	218.	219.	219.	220.
FUEL IN	DEG F	110.	114.	110.	111.	112.	114.
FUEL RETURN	DEG F	152.	157.	151.	151.	152.	154.
FUEL SUPPLY	DEG F	93.	100.	93.	95.	95.	99.
FUEL COOLER	DEG F	111.	117.	112.	112.	113.	115.
INTAKE AIR	DEG F	89.	95.	82.	87.	86.	96.
TURB. INLET (L)	DEG F	921.	929.	902.	916.	921.	935.
TURB. INLET (R)	DEG F	931.	939.	914.	924.	931.	945.
COMP. OUT (L)	DEG F	228.	234.	218.	225.	225.	234.
COMP. OUT (R)	DEG F	226.	233.	217.	222.	223.	232.
CHARGE AIR (L)	DEG F	193.	192.	187.	189.	189.	192.
CHARGE AIR (R)	DEG F	193.	193.	188.	190.	190.	192.
EXH. STACK (R)	DEG F	788.	793.	771.	781.	786.	802.
EXH. STACK (L)	DEG F	775.	782.	756.	768.	774.	790.
WATER INLET	DEG F	101.	110.	102.	104.	102.	108.
CELL AIR	DEG F	91.	99.	81.	86.	88.	96.
EXHAUST 1R	DEG F	915.	925.	896.	907.	914.	930.
EXHAUST 2R	DEG F	893.	901.	876.	896.	898.	911.
EXHAUST 3R	DEG F	910.	921.	892.	903.	904.	919.
EXHAUST 4R	DEG F	883.	895.	869.	881.	882.	996.
EXHAUST 5R	DEG F	902.	914.	886.	893.	895.	911.
EXHAUST 6R	DEG F	914.	928.	900.	906.	913.	923.
EXHAUST 1L	DEG F	968.	983.	946.	949.	954.	971.
EXHAUST 2L	DEG F	927.	938.	908.	916.	920.	938.
EXHAUST 3L	DEG F	891.	901.	872.	892.	890.	906.
EXHAUST 4L	DEG F	898.	906.	879.	888.	892.	910.
EXHAUST 5L	DEG F	902.	914.	884.	893.	897.	913.
EXHAUST 6L	DEG F	911.	932.	898.	911.	917.	932.
OIL PRESSURE	PSI	75.	76.	76.	76.	76.	76.
RAIL PRESSURE	PSI	90.0	88.0	90.0	90.0	88.0	90.0
BOOST (R)	PSI	10.3	10.2	10.3	10.4	10.2	10.0
BOOST (L)	PSI	10.9	10.8	10.8	10.5	10.1	10.5
INLET VAC. (R)	IN-H2O	12.0	12.8	13.1	13.5	14.1	15.4
EXH. PRESS. (R)	PSI	.3	.3	.2	.2	.1	.2
EXH. PRESS. (L)	PSI	.5	.5	.5	.4	.5	.5
TURB. IN. (R)	IN-HG	10.5	10.3	10.5	10.4	10.2	10.0
TURB. IN. (L)	IN-HG	9.2	9.0	9.1	9.2	9.0	9.0
FUEL PRESS.	PSI	22.	22.	20.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	2.	2.	2.	2.
WATER PRESS.	PSI	60.	50.	50.	60.	65.	65.
HYDROCARBONS	PPMC	46.	150.	94.	54.	65.	67.
CARBON MONOXIDE	PPM	212.	571.	468.	186.	130.	163.
NITRIC OXIDE	PPM	1018.	988.	950.	675.	695.	700.
NITROGEN OXIDES	PPM	983.	975.	963.	813.	708.	740.
CARBON DIOXIDE	PCT	7.2	7.6	7.5	7.6	7.6	8.1
OXYGEN	PCT	10.3	8.7	12.0	11.9	13.0	11.6
SMOKE OPACITY	PCT	0.0	4.7	3.0	2.6	3.5	3.0
HC MASS	GM-HR	55.774	171.43	107.30	60.978	73.797	72.733
CO MASS	GM-HR	485.17	1222.3	1009.6	399.94	279.54	333.28
NOX MASS	GM-HR	4382.4	6479.9	4473.2	3662.0	3228.9	3051.5
BSHC	GM/BHP-HR	.1269	.3706	.2449	.1385	.1662	.1620
BSCO	GM/BHP-HR	1.1041	2.6425	2.3039	.9086	.6296	.7424
BSNO	GM/BHP-HR	9.9733	14.009	10.208	8.3195	7.2722	6.7974

TABLE C-17. ENGINE TEST RESULTS, CUMMINS ENGINE, 1800 RPM, 20% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		175.	187	199	221.	235	249
NOM. WATER PCT		20.	20.	20	20	20	20
ENGINE SPEED	RPM	1800.	1800.	1800	1800	1800.	1800
OBS. TORQUE	LB-FT	1257.	1257	1257.	1257.	1257.	1257
BAR. PRESS.	IN-HG	29.21	28.88	29.24	29.25	29.03	28.95
DRY BULB	DEG F	90	98.	82.	86.	87.	97.
WET BULB	DEG F	73.	84.	76.	76.	77.	79
REL. HUMIDITY	PCT	44.	56.	76.	63.	64.	45.
CORR. BHP	HP	440.5	455.4	437.6	439.6	445.8	451.2
CORR. BMEP	PSI	113.4	117.2	112.6	113.1	114.7	116.1
FUEL FLOW	LB/HR	177.48	178.82	176.82	176.64	175.61	178.35
WATER FLOW	CC/MIN	398.0	394.5	394.5	394.5	384.0	394.5
CALC. VOL. %	PCT.	19.7	19.4	19.7	19.7	19.3	19.5
BSFC	LB/BHP-HR	.4029	.3927	.4040	.4018	.3939	.3952
AIR FLOW	LB/MIN	79.6	78.0	80.8	80.4	77.8	76.2
STOICH. F/A		.0691	.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0371	.0382	.0365	.0366	.0376	.0390
CALC. F/A		.0334	.0356	.0357	.0356	.0358	.0372
% DIFF	PCT	-10.00	-6.80	-2.20	-2.77	-4.80	-4.66
COOLANT IN	DEG F	177.	172.	171.	164	175.	174.
COOLANT OUT	DEG F	188.	184.	185.	181.	186.	185
OIL SUMP	DEG F	223.	219.	217	217	219.	221
FUEL IN	DEG F	110.	115.	108.	111	112	115.
FUEL RETURN	DEG F	152.	157.	148	147	151	153
FUEL SUPPLY	DEG F	94	102.	92.	95	95.	100
FUEL COOLER	DEG F	112.	124.	110	111	113.	116
INTAKE AIR	DEG F	91.	97.	81	86.	90.	98.
TURB. INLET (L)	DEG F	906.	906.	887.	898.	905.	921
TURB. INLET (R)	DEG F	919.	920.	899	908	917	935
COMP. OUT (L)	DEG F	226.	231.	216	221.	224.	233.
COMP. OUT (R)	DEG F	227.	232.	215	218	222	232
CHARGE AIR (L)	DEG F	192.	193.	186.	184	189.	191
CHARGE AIR (R)	DEG F	193.	194.	187.	184.	189.	192.
EXH. STACK (R)	DEG F	778.	779.	760	768	777	794
EXH. STACK (L)	DEG F	764.	765.	745	752.	762	778
WATER INLET	DEG F	102.	115.	99	101.	101.	107
CELL AIR	DEG F	94.	100.	83.	88	91.	98.
EXHAUST 1R	DEG F	901.	915.	880.	896.	905.	921.
EXHAUST 2R	DEG F	881.	888.	868.	885	890.	899.
EXHAUST 3R	DEG F	900.	906.	879.	891.	897.	912.
EXHAUST 4R	DEG F	873.	885.	853.	868	873.	888.
EXHAUST 5R	DEG F	892.	905.	881.	884	890.	903.
EXHAUST 6R	DEG F	902.	913.	888.	894	898.	912.
EXHAUST 1L	DEG F	953.	964.	928.	932.	939.	957.
EXHAUST 2L	DEG F	916.	923.	896	906.	913.	928.
EXHAUST 3L	DEG F	878.	885.	859.	877.	880.	891.
EXHAUST 4L	DEG F	883.	883.	862.	872.	882.	894.
EXHAUST 5L	DEG F	894.	900.	873	884.	892.	904.
EXHAUST 6L	DEG F	904.	914	883	902.	904.	920.
OIL PRESSURE	PSI	75.	76.	76.	77.	76	76.
RAIL PRESSURE	PSI	97.0	98.0	96.0	95.0	96.0	97.0
BOOST (R)	PSI	10.0	9.8	10.0	10.0	9.9	9.8
BOOST (L)	PSI	10.5	10.0	110.8	10.0	10.0	10.0
INLET VAC. (R)	IN-H2O	11.8	12.7	12.9	13.3	13.9	15.3
EXH. PRESS. (R)	PSI	.3	.2	.2	.1	.2	.1
EXH. PRESS. (L)	PSI	.5	.5	.5	.5	.5	.5
TURB. IN. (R)	IN-HG	10.0	10.0	10.2	10.0	10.0	10.0
TURB. IN. (L)	IN-HG	9.0	9.0	9.1	9.0	9.0	9.0
FUEL PRESS.	PSI	22.	22.	20	20	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	2	3.	2.	2
WATER PRESS.	PSI	60.	65.	60	60.	65.	65.
HYDROCARBONS	PPMC	47.	144.	95	55.	56.	69.
CARBON MONOXIDE	PPM	163.	281.	448.	164.	148.	154.
NITRIC OXIDE	PPM	1125.	1025.	1000	880.	733.	688.
NITROGEN OXIDES	PPM	1100	1050	1013	705	770	713.
CARBON DIOXIDE	PCT	7.2	7.7	7.7	7.7	7.8	8.1
OXYGEN	PCT	10.2	8.8	11.9	11.8	12.8	11.6
SMOKE OPACITY	PCT	0.0	4.0	2.7	2.4	3.3	2.8
HC MASS	GM-HR	55.778	163.08	106.31	61.570	61.964	74.740
CO MASS	GM-HR	368.94	598.46	942.87	344.31	307.07	312.68
NOX MASS	GM-HR	5115.1	5482.2	4872.0	3304.0	3601.3	3189.8
BSHC	GM/BHP-HR	.1266	.3581	.2429	.1401	.1390	.1656
BSCO	GM/BHP-HR	.8375	1.3143	2.1545	.7832	.6888	.6930
BSNO	GM/BHP-HR	11.611	12.039	11.133	7.5156	8.0784	7.0691

TABLE C-18. ENGINE TEST RESULTS, CUMMINS ENGINE, 1800 RPM, 25% WATER

DYNAMOMETER CONSTANT: 3000 API GRAVITY OF DIESEL FUEL: 35.3 AT 60F
H/C RATIO: 1.78

RUN NUMBER		176.	200.	222.	236.	250.
NOM. WATER PCT.		25.	25.	25.	25.	25.
ENGINE SPEED	RPM	1800.	1800.	1800.	1800.	1800.
OBS. TORQUE	LB-FT	1257.	1257.	1257.	1257.	1257.
BAR. PRESS.	IN-HG	29.19	29.26	29.25	29.03	28.92
DRY BULB	DEG F	90.	81.	86.	91.	98.
WET BULB	DEG F	73.	75.	76.	79.	77.
REL. HUMIDITY	PCT	44.	76.	63.	59.	39.
CORR. BHP	HP	440.3	436.9	441.9	445.9	450.7
CORR. BMEP	PSI	113.3	112.4	113.7	114.7	116.0
FUEL FLOW	LB/HR	178.04	176.54	176.64	176.71	179.43
WATER FLOW	CC/MIN	478.9	494.2	501.7	501.7	501.7
CALC. VOL. %	PCT	22.8	23.5	23.7	23.7	23.4
BSFC	LB/BHP-HR	.4044	.4041	.3998	.3963	.3981
AIR FLOW	LB/MIN	79.8	80.1	77.7	77.9	76.1
STOICH. F/A		.0691	.0691	.0691	.0691	.0691
MEAS. F/A		.0372	.0368	.0379	.0378	.0393
CALC. F/A		.0334	.0356	.0358	.0362	.0369
% DIFF.	PCT	-10.05	-3.00	-5.39	-4.07	-6.10
COOLANT IN	DEG F	177.	174.	162.	174.	176.
COOLANT OUT	DEG F	188.	186.	180.	185.	186.
OIL SUMP	DEG F	223.	219.	217.	219.	221.
FUEL IN	DEG F	110.	109.	112.	112.	117.
FUEL RETURN	DEG F	150.	149.	147.	149.	154.
FUEL SUPPLY	DEG F	95.	93.	97.	95.	102.
FUEL COOLER	DEG F	110.	111.	112.	113.	117.
INTAKE AIR	DEG F	90.	81.	90.	89.	99.
TURB. INLET (L)	DEG F	892	872.	881.	884.	909.
TURB. INLET (R)	DEG F	906.	886.	894.	900.	924.
COMP. OUT (L)	DEG F	225.	213.	221.	221.	232.
COMP. OUT (R)	DEG F	222.	212.	219.	219.	230.
CHARGE AIR (L)	DEG F	191.	187.	184.	188.	192.
CHARGE AIR (R)	DEG F	191.	188.	184.	188.	192.
EXH. STACK (R)	DEG F	769.	749.	758.	765.	787.
EXH. STACK (L)	DEG F	754.	733.	742.	746.	771.
WATER INLET	DEG F	100.	99.	102.	100.	109.
CELL AIR	DEG F	94.	80.	[illegible]0.	92.	100.
EXHAUST 1R	DEG F	893.	872.	881.	894.	907.
EXHAUST 2R	DEG F	824.	857.	868.	876.	884.
EXHAUST 3R	DEG F	893.	853.	880.	888.	899.
EXHAUST 4R	DEG F	864.	849.	853.	867.	877.
EXHAUST 5R	DEG F	889.	873.	875.	882.	897.
EXHAUST 6R	DEG F	883.	878.	880.	894.	905.
EXHAUST 1L	DEG F	940.	917.	908.	920.	939.
EXHAUST 2L	DEG F	907.	889.	894.	905.	919.
EXHAUST 3L	DEG F	868.	848.	855.	867.	877.
EXHAUST 4L	DEG F	874.	855.	853.	867.	879.
EXHAUST 5L	DEG F	885.	872.	875.	882.	894.
EXHAUST 6L	DEG F	894.	872.	880.	894.	908.
OIL PRESSURE	PSI	75.	76.	77.	76.	76.
RAIL PRESSURE	PSI	102.0	104.0	107.0	112.0	105.0
BOOST (R)	PSI	9.8	10.0	9.8	9.7	9.5
BOOST (L)	PSI	9.8	10.0	10.0	10.0	9.8
INLET VAC. (R)	IN-H2O	11.7	12.7	13.0	13.6	15.1
EXH. PRESS. (R)	PSI	.3	.1	.1	.1	.1
EXH. PRESS. (L)	PSI	.5	.5	.5	.5	.5
TURB. IN. (R)	IN-HG	10.0	10.0	10.0	10.0	10.0
TURB. IN. (L)	IN-HG	9.0	9.0	9.0	88.8	8.8
FUEL PRESS.	PSI	22.	20.	20.	20.	20.
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.	2.	3.	2.	2.
WATER PRESS.	PSI	60.	60.	70.	62.	65.
HYDROCARBONS	PPMC	46.	100.	55.	55.	69.
CARBON MONOXIDE	PPM	163.	429.	148.	151.	148.
NITRIC OXIDE	PPM	1188.	1113.	770.	788.	748.
NITROGEN OXIDES	PPM	1163.	1113.	750.	795.	763.
CARBON DIOXIDE	PCT	7.2	7.7	7.8	7.9	8.0
OXYGEN	PCT	10.0	11.9	12.5	13.3	11.3
SMOKE OPACITY	PCT	0.0	2.4	2.2	3.1	2.8
HC MASS	GM-HR	55.392	111.82	61.187	60.594	75.734
CO MASS	GM-HR	370.11	900.50	308.49	311.64	303.91
NOX MASS	GM-HR	5662.8	5600.0	3712.8	4021.8	3517.1
BSHC	GM/BHP-HR	.1258	.2560	.1385	.1359	.1680
BSCO	GM/BHP-HR	.8406	2.0613	.6982	.6989	.6743
BSNO	GM/BHP-HR	12.862	12.819	8.4027	9.0196	7.8030

TABLE C-19. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 500 RPM

DYNAMOMETER CONSTANT: **2000**. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		1.	7.	13.	47.	48.	49.	50.
NOM. WATER PCT.		0.	0.	0.	0.	5.	10.	15.
ENGINE SPEED	RPM	600.	600.	600.	600.	600.	600.	600.
OBS. TORQUE	LB-FT	386.	386.	386.	386.	386.	386.	386.
BAR. PRESS.	IN-HG	29.26	29.30	29.07	29.02	29.03	28.99	28.94
DRY BULB	DEG F	72.	70.	72.	72.	78.	79.	69.
WET BULB	DEG F	64.	63.	66.	59.	60.	61.	56.
REL. HUMIDITY	PCT	65.	68.	73.	46.	34.	35.	44.
CORR. BHP	HP	43.6	43.6	44.6	44.5	44.4	44.6	44.4
CORR. BMEP	PSI	16.1	16.1	16.5	16.4	16.4	16.5	16.4
FUEL FLOW	LB/HR	24.89	24.41	24.60	23.82	23.43	24.22	24.60
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	11.5	20.6	33.8
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	5.2	8.7	13.3
BSFC	LB/BHP-HR	.5712	.5604	.5515	.5358	.5279	.5431	.5542
AIR FLOW L	LB/MIN	24.0	23.1	22.6	22.5	22.3	22.1	22.0
AIR FLOW R	LB/MIN	24.7	23.6	23.0	21.6	21.2	21.1	21.2
COOLANT IN	DEG F	179.	177.	179.	180.	179.	179.	182.
COOLANT OUT	DEG F	184.	183.	183.	185.	184.	184.	187.
OIL SUMP	DEG F	193.	194.	192.	192.	191.	192.	194.
FUEL IN	DEG F	95.	93.	92.	97.	93.	92.	98.
FUEL RETURN	DEG F	119.	119.	116.	121	117.	115.	119.
FUEL SUPPLY	DEG F	98.	91.	102.	116.	112.	112.	112.
FUEL COOLER	DEG F	93.	93.	90.	95.	90	90.	95.
INTAKE AIR (RF)	DEG F	74.	81.	85.	82.	84.	85	85.
INTAKE AIR (RR)	DEG F	75.	80.	78.	81.	84.	84.	84.
INTAKE AIR (LF)	DEG F	73.	78.	78.	81.	83.	85.	82.
INTAKE AIR (LR)	DEG F	73.	77.	80.	82.	84.	85.	82.
HP AIR (RF)	DEG F	84.	92.	88.	92.	93.	94.	92.
HP AIR (RR)	DEG F	85.	93.	89.	92.	94.	94	93.
HP AIR (LF)	DEG F	85.	91.	91.	93.	95.	96	93.
HP AIR (LR)	DEG F	84.	88.	89.	91.	92.	94.	91.
EXH. STACK	DEG F	299.	346.	301.	307.	303.	300	297.
WATER INLET	DEG F	69.	69.	78.	80.	81.	81.	84.
CELL AIR	DEG F	69.	70.	80.	82.	82.	84	80.
EXHAUST 1R	DEG F	319.	320.	324.	330.	326.	324.	328
EXHAUST 2R	DEG F	306.	310.	310.	315.	315.	315	315
EXHAUST 3R	DEG F	305.	306.	305.	308.	305.	304.	307
EXHAUST 4R	DEG F	313.	313.	316.	314.	312.	311.	314
EXHAUST 5R	DEG F	303.	303.	308.	306.	303.	303.	344.
EXHAUST 6R	DEG F	299.	290.	297.	306.	302.	301.	305
EXHAUST 1L	DEG F	337.	344.	342	337.	332.	331.	333.
EXHAUST 2L	DEG F	320.	323.	324.	328.	327.	319.	370.
EXHAUST 3L	DEG F	316.	320.	321.	324.	318.	316.	316
EXHAUST 4L	DEG F	326.	332.	330.	330.	328.	325	326
EXHAUST 5L	DEG F	331.	339.	337	342.	338.	335	335.
EXHAUST 6L	DEG F	335.	339.	340.	338.	337.	333.	331
OIL PRESSURE	PSI	20.0	18.0	19.0	19.0	19.0	19.0	19.0
FUEL SPILL	PSI	20.0	20.0	22.0	20.0	20.0	20.0	20.0
BOOST (RF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (RR)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AIR BOX	PSI	0.0	0.0	0.0	8.0	8.0	8.0	8.0
INLET VAC. (RF)	IN-H2O	.5	.4	.5	.5	.5	.5	.5
INLET VAC. (RR)	IN-H2O	.6	.4	.5	.5	.5	.5	.5
INLET VAC. (LF)	IN-H2O	1.8	1.7	1.8	1.9	1.8	1.8	1.8
INLET VAC. (LR)	IN-H2O	1.7	1.7	1.8	1.8	1.8	1.8	1.8
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	0.0	0.0	0.0	.9	.8	.8	.8
TURB. IN. (RR)	IN-HG	0.0	0.0	0.0	.9	.8	.8	.8
TURB. IN. (LF)	IN-HG	0.0	0.0	0.0	.9	.8	.8	.8
TURB. IN. (LR)	IN-HG	0.0	0.0	0.0	.9	.8	.8	.8
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100	100	100
FUEL SUPPLY	PSI	4.0	3.7	4.0	3.5	4.0	4.0	4.5
WATER PRESS	PSI	0.	0.	0.	0.	50.	50	50

TABLE C-20. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 800 RPM, BASELINE

DYNAMOMETER CONSTANT: 2000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		2.	8.	14.	40.	46.
NOM. WATER PCT.		0.	0.	0.	0.	0.
ENGINE SPEED	RPM	800.	800.	800.	800.	800.
OBS. TORQUE	LB-FT	591.	591.	591.	591.	591.
BAR. PRESS.	IN-HG	29.20	29.29	29.04	29.33	29.13
DRY BULB	DEG F	72.	74.	74.	71.	79.
WET BULB	DEG F	64.	64.	68.	58.	62.
REL. HUMIDITY	PCT	65.	58.	74.	45.	38.
CORR. BHP	HP	89.8	89.5	91.0	88.4	90.4
CORR. BMEP	PSI	24.9	24.8	25.2	24.5	25.0
FUEL FLOW	LB/HR	43.10	43.06	42.87	42.15	42.43
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	0.0
BSFC	LB/BHP-HR	.4799	.4813	.4710	.4768	.4692
AIR FLOW L	LB/MIN	31.9	31.9	31.0	31.0	30.8
AIR FLOW R	LB/MIN	32.7	32.6	31.6	31.1	29.8
COOLANT IN	DEG F	180.	180.	181.	180.	179.
COOLANT OUT	DEG F	186.	185.	186.	185.	185.
OIL SUMP	DEG F	196.	196.	197.	195.	196.
FUEL IN	DEG F	99.	95.	95.	95.	102.
FUEL RETURN	DEG F	120.	117.	117.	118.	123.
FUEL SUPPLY	DEG F	95.	90.	91.	96.	108.
FUEL COOLER	DEG F	99.	93.	93.	95.	100.
INTAKE AIR (RF)	DEG F	79.	85.	89.	76.	87.
INTAKE AIR (RR)	DEG F	79.	85.	81.	75.	86.
INTAKE AIR (LF)	DEG F	80.	79.	78.	72.	84.
INTAKE AIR (LR)	DEG F	81.	79.	80.	74.	84.
HP AIR (RF)	DEG F	92.	98.	95.	90.	100.
HP AIR (RR)	DEG F	93.	98.	95.	90.	100.
HP AIR (LF)	DEG F	93.	92.	95.	89.	99.
HP AIR (LR)	DEG F	94.	92.	93.	88.	97.
EXH. STACK	DEG F	362.	368.	370.	379.	378.
WATER INLET	DEG F	75.	73.	75.	78.	87.
CELL AIR	DEG F	75.	75.	78.	71.	82.
EXHAUST 1R	DEG F	385.	386.	393.	402.	402.
EXHAUST 2R	DEG F	368.	371.	375.	381.	380.
EXHAUST 3R	DEG F	363.	360.	370.	370.	368.
EXHAUST 4R	DEG F	377.	375.	381.	384.	382.
EXHAUST 5R	DEG F	364.	384.	370.	370.	370.
EXHAUST 6R	DEG F	368.	364.	368.	373.	372.
EXHAUST 1L	DEG F	418.	418.	426.	431.	426.
EXHAUST 2L	DEG F	396.	398.	403.	406.	400.
EXHAUST 3L	DEG F	381.	381.	386.	390.	388.
EXHAUST 4L	DEG F	407.	411.	414.	416.	420.
EXHAUST 5L	DEG F	413.	417.	424.	432.	430.
EXHAUST 6L	DEG F	420.	125.	426.	435.	434.
OIL PRESSURE	PSI	26.0	27.0	26.0	26.0	26.0
FUEL SPILL	PSI	28.0	29.0	28.0	25.0	25.0
BOOST (RF)	PSI	.5	0.0	0.0	.5	.5
BOOST (RR)	PSI	1.0	0.0	0.0	.5	.5
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.0	0.0	0.0	.5	.5
AIR BOX	PSI	0.0	1.0	0.0	8.0	8.0
INLET VAC. (RF)	IN-H2O	.9	.9	.9	1.0	1.0
INLET VAC. (RR)	IN-H2O	1.0	.9	.9	1.0	1.0
INLET VAC. (LF)	IN-H2O	2.6	2.7	2.8	2.8	2.8
INLET VAC. (LR)	IN-H2O	2.7	2.6	2.8	2.7	2.8
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	0.0	.8	0.0	1.8	1.8
TURB. IN. (RR)	IN-HG	0.0	.8	0.0	1.8	1.7
TURB. IN. (LF)	IN-HG	0.0	.8	0.0	1.8	1.7
TURB. IN. (LR)	IN-HG	0.0	.8	0.0	1.8	1.7
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	4.5	3.7	3.5	3.0	3.7
WATER PRESS.	PSI	0.	0.	0.	0.	0.

TABLE C-21. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 800 RPM, WITH WATER ADDITION

DYNAMOMETER CONSTANT: **2000.** API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		41.	42.	43.	44.	45.
NOM. WATER PCT.		5.	10.	15.	20.	25.
ENGINE SPEED	RPM	800.	800.	800.	800.	800.
OBS. TORQUE	LB-FT	591.	591.	591.	591.	591.
BAR. PRESS.	IN-HG	29.32	29.30	29.26	29.21	29.17
DRY BULB	DEG F	80.	80.	80.	79.	79.
WET BULB	DEG F	60.	61.	61.	59.	59.
REL. HUMIDITY	PCT	29.	32.	32.	29.	29.
CORR. BHP	HP	89.8	90.0	90.3	89.9	90.5
CORR. BMEP	PSI	24.9	24.9	25.0	24.9	25.0
FUEL FLOW	LB/HR	42.60	42.83	43.28	44.19	43.69
WATER FLOW	CC/MIN	19.7	40.0	66.4	90.9	119.3
CALC. VOL. %	PCT.	4.9	9.4	14.6	18.6	23.3
BSFC	LB/BHP-HR	.4742	.4760	.4791	.4916	.4829
AIR FLOW L	LB/MIN	31.1	30.9	30.6	31.6	30.6
AIR FLOW R	LB/MIN	30.0	30.0	30.6	30.0	29.9
COOLANT IN	DEG F	180.	180.	181.	180.	179.
COOLANT OUT	DEG F	185.	186.	186.	185.	185.
OIL SUMP	DEG F	197.	197.	197.	198.	197.
FUEL IN	DEG F	103.	104.	99.	99.	95.
FUEL RETURN	DEG F	123.	123.	118.	117.	114.
FUEL SUPPLY	DEG F	101.	102.	101.	100.	100.
FUEL COOLER	DEG F	102.	102.	97.	98.	93.
INTAKE AIR (RF)	DEG F	86.	89.	88.	85.	88.
INTAKE AIR (RR)	DEG F	85.	89.	88.	85.	88.
INTAKE AIR (LF)	DEG F	84.	86.	85.	82.	86.
INTAKE AIR (LR)	DEG F	85.	87.	87.	84.	88.
HP AIR (RF)	DEG F	99.	103.	102.	98.	102.
HP AIR (RR)	DEG F	99.	103.	102.	99.	102.
HP AIR (LF)	DEG F	100.	102.	101.	97.	102.
HP AIR (LR)	DEG F	99.	100.	100.	96.	100.
EXH. STACK	DEG F	378.	375.	368.	363.	363.
WATER INLET	DEG F	78.	83.	85.	83.	83.
CELL AIR	DEG F	84.	84.	86.	82.	86.
EXHAUST 1R	DEG F	400.	396.	392.	390.	388.
EXHAUST 2R	DEG F	379.	376.	375.	376.	374.
EXHAUST 3R	DEG F	366.	366.	363.	364.	364.
EXHAUST 4R	DEG F	380.	378.	376.	373.	373.
EXHAUST 5R	DEG F	369.	366.	363.	362.	362.
EXHAUST 6R	DEG F	372.	373.	371.	370.	369.
EXHAUST 1L	DEG F	426.	417.	411.	405.	404.
EXHAUST 2L	DEG F	401.	395.	389.	385.	384.
EXHAUST 3L	DEG F	388.	384.	379.	376.	375.
EXHAUST 4L	DEG F	415.	411.	404.	399.	401.
EXHAUST 5L	DEG F	424.	421.	412.	407.	107.
EXHAUST 6L	DEG F	428.	424.	416.	409.	109.
OIL PRESSURE	PSI	26.0	26.0	26.0	26.0	26.0
FUEL SPILL	PSI	25.0	25.0	27.0	27.0	27.0
BOOST (RF)	PSI	.5	.5	.5	.5	.5
BOOST (RR)	PSI	.5	.5	.5	.5	.5
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	.5	.5	.5	.5	.5
AIR BOX	PSI	8.0	8.0	8.0	8.0	8.0
INLET VAC. (RF)	IN-H2O	1.0	1.0	1.0	1.0	1.0
INLET VAC. (RR)	IN-H2O	1.0	1.0	1.0	1.0	1.0
INLET VAC. (LF)	IN-H2O	2.8	2.8	2.8	2.8	2.8
INLET VAC. (LR)	IN-H2O	2.8	2.8	2.8	2.7	2.8
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	1.8	1.8	1.8	1.8	1.8
TURB. IN. (RR)	IN-HG	1.9	1.8	1.7	1.8	1.7
TURB. IN. (LF)	IN-HG	1.8	1.8	1.7	1.8	1.7
TURB. IN. (LR)	IN-HG	1.8	1.8	1.8	1.8	1.8
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.0	3.5	4.0	4.5	5.0
WATER PRESS.	PSI	50.	50.	50.	50.	50.

TABLE C-22. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1000 RPM, BASELINE

DYNAMOMETER CONSTANT: 2000.   API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		3.	9.	15.	19.	25.	51.	57.	65.	71.
NOM. WATER PCT.		0.	0.	0.	0.	0.	0.	0.	0.	0.
ENGINE SPEED	RPM	1000.	1000.	1000.	1000.	1000.	1000.	1000.	1000.	1000.
OBS. TORQUE	LB-FT	877.	877.	877.	877.	877.	877.	877.	877.	877.
BAR. PRESS.	IN-HG	29.17	29.26	28.99	29.33	29.25	29.29	29.15	29.07	29.00
DRY BULB	DEG F	72.	72.	74.	73.	73.	62.	68.	67.	71.
WET BULB	DEG F	64.	64.	68.	66.	67.	55.	62.	62.	64.
REL. HUMIDITY	PCT	65.	65.	74.	69.	73.	64.	72.	76.	69.
CORR. BHP	HP	167.0	165.9	169.6	166.4	168.4	162.9	166.2	168.2	167.2
CORR. BMEP	PSI	37.0	36.7	37.6	36.9	37.3	36.1	36.8	37.3	37.0
FUEL FLOW	LB/HR	72.43	72.17	71.76	72.25	72.43	71.91	73.17	71.97	71.32
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BSFC	LB/BHP-HR	.4336	.4351	.4230	.4341	.4301	.4416	.4403	.4278	.4265
AIR FLOW L	LB/MIN	40.7	40.7	39.8	40.9	39.9	41.4	41.0	39.6	41.0
AIR FLOW R	LB/MIN	41.8	42.0	40.8	41.5	40.2	41.6	40.8	40.2	39.9
COOLANT IN	DEG F	179.	179.	179.	177.	182.	178.	176.	178.	174.
COOLANT OUT	DEG F	185.	186.	186.	184.	188.	184.	182.	184.	182.
OIL SUMP	DEG F	201.	201.	201.	200.	202.	198.	197.	198.	198.
FUEL IN	DEG F	102.	99.	99.	100.	100.	103.	100.	97.	100.
FUEL RETURN	DEG F	122.	120.	121.	121.	121.	122.	120.	119.	120.
FUEL SUPPLY	DEG F	89.	86.	87.	86.	88.	85.	84.	81.	88.
FUEL COOLER	DEG F	100.	96.	98.	100.	99.	102.	100.	96.	90.
INTAKE AIR (RF)	DEG F	81.	89.	89.	84.	89.	73.	82.	78.	79.
INTAKE AIR (RR)	DEG F	81.	89.	89.	84.	89.	72.	81.	78.	79.
INTAKE AIR (LF)	DEG F	79.	80.	82.	81.	86.	68.	75.	73.	77.
INTAKE AIR (LR)	DEG F	81.	80.	83.	82.	86.	68.	75.	73.	78.
HP AIR (RF)	DEG F	102.	111.	111.	106.	110.	92.	102.	98.	98.
HP AIR (RR)	DEG F	103.	111.	111.	107.	111.	93.	102.	99.	99.
HP AIR (LF)	DEG F	103.	103.	107.	106.	110.	92.	98.	96.	99.
HP AIR (LR)	DEG F	103.	103.	104.	105.	109.	90.	96.	94.	100.
EXH. STACK	DEG F	442.	451.	453.	461.	457.	468.	472.	476.	469.
WATER INLET	DEG F	74.	78.	76.	79.	79.	70.	73.	73.	75.
CELL AIR	DEG F	76.	73.	80.	76.	82.	64.	72.	79.	72.
EXHAUST 1R	DEG F	479.	485.	489.	486.	494.	481.	487.	486.	479.
EXHAUST 2R	DEG F	459.	463.	469.	466.	472.	459.	459.	463.	458.
EXHAUST 3R	DEG F	466.	466.	475.	476.	473.	455.	460.	457.	452.
EXHAUST 4R	DEG F	477.	481.	487.	481.	481.	466.	469.	474.	471.
EXHAUST 5R	DEG F	462.	464.	466.	466.	466.	447.	488.	453.	452.
EXHAUST 6R	DEG F	465.	470.	474.	474.	480.	460.	457.	463.	458.
EXHAUST 1L	DEG F	505.	508.	514.	512.	514.	527.	527.	535.	528.
EXHAUST 2L	DEG F	495.	499.	504.	505.	509.	522.	524.	533.	526.
EXHAUST 3L	DEG F	471.	476.	483.	480.	480.	495.	497.	506.	500.
EXHAUST 4L	DEG F	495.	503.	505.	506.	567.	524.	526.	483.	474.
EXHAUST 5L	DEG F	508.	518.	523.	519.	521.	537.	544.	549.	544.
EXHAUST 6L	DEG F	534.	537.	537.	543.	538.	557.	552.	568	563.
OIL PRESSURE	PSI	34.0	35.0	34.0	35.0	34.0	34.0	35.0	35.0	35.0
FUEL SPILL	PSI	37.0	37.0	37.0	36.0	36.0	35.0	35.0	35.0	35.0
BOOST (RF)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (RR)	PSI	1.0	1.0	1.0	2.0	2.0	0.0	0.0	0.0	0.0
BOOST (LF)	PSI	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AIR BOX	PSI	0.0	2.0	4.0	4.0	5.0	10.0	10.0	10.0	10.0
INLET VAC. (RF)	IN-H2O	1.6	1.7	1.5	1.6	1.6	1.5	1.5	1.5	1.4
INLET VAC. (RR)	IN-H2O	1.7	1.7	1.6	1.7	1.5	1.5	1.5	1.6	1.6
INLET VAC. (LF)	IN-H2O	3.9	3.8	4.0	4.0	3.9	3.9	4.0	4.0	4.0
INLET VAC. (LR)	IN-H2O	3.8	3.8	3.9	3.9	3.9	3.8	3.9	4.0	4.0
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	0.0	1.2	1.2	3.7	2.4	3.2	3.1	3.1	3.0
TURB. IN. (RR)	IN-HG	0.0	.8	1.2	3.7	2.4	3.1	3.1	3.2	3.0
TURB. IN. (LF)	IN-HG	0.0	1.0	1.0	3.7	2.4	3.0	3.1	3.1	3.0
TURB. IN. (LR)	IN-HG	0.0	.8	1.2	3.7	2.4	3.2	3.3	3.2	3.2
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	4.2	3.7	3.5	3.5	3.2	2.5	3.7	2.5	3.5
WATER PRESS.	PSI	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE C-23. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1000 RPM, 5, 10, 15% WATER

DYNAMOMETER CONSTANT: 2000.   API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		20.	52.	66.	21.	53.	67.	22.	54.	68.
NOM. WATER PCT.		5.	5.	5.	10.	10.	10.	15.	15.	15.
ENGINE SPEED	RPM	1000.	1000.	1000.	1000.	1000.	1000.	1000.	1000.	1000.
OBS. TORQUE	LB-FT	877.	877.	877.	877.	877.	877.	877.	877.	877.
BAR. PRESS.	IN-HG	29.33	29.30	29.08	29.33	29.28	29.09	29.31	29.25	29.09
DRY BULB	DEG F	73.	62.	67.	73.	68.	72.	72.	68.	72.
WET BULB	DEG F	66.	55.	62.	66.	58.	66.	66.	58.	66.
REL. HUMIDITY	PCT	69.	64.	76.	69.	55.	73.	73.	55.	73.
CORR. BHP	HP	168.2	163.2	167.1	168.6	164.3	167.9	168.8	164.5	167.9
CORR. BMEP	PSI	37.2	36.2	37.0	37.3	36.4	37.2	37.4	36.4	37.2
FUEL FLOW	LB/HR	72.55	71.96	71.68	73.11	72.06	72.35	73.34	72.52	72.37
WATER FLOW	CC/MIN	33.8	32.3	30.8	66.4	69.7	66.4	111.0	109.5	111.0
CALC. VOL. %	PCT	4.9	4.8	4.6	9.2	9.7	9.3	14.4	14.4	14.6
BSFC	LB/BHP-HR	.4314	.4408	.4290	.4337	.4385	.4309	.4345	.4409	.4310
AIR FLOW L	LB/MIN	39.8	41.4	40.4	39.5	40.8	40.5	39.5	40.9	40.2
AIR FLOW R	LB/MIN	40.7	41.5	40.2	40.1	41.1	40.3	40.1	41.3	40.0
COOLANT IN	DEG F	177.	177.	180.	179.	181.	177.	182.	180.	177.
COOLANT OUT	DEG F	184.	184.	186.	185.	187.	184.	188.	189.	184.
OIL SUMP	DEG F	199.	199.	201.	200.	201.	198.	203.	202.	199.
FUEL IN	DEG F	98.	97.	99.	98.	98.	100.	99.	99.	98.
FUEL RETURN	DEG F	119.	118.	120.	120.	118.	119.	118.	118.	117.
FUEL SUPPLY	DEG F	87.	82.	86.	89.	85.	87.	87.	86.	87.
FUEL COOLER	DEG F	96.	98.	99.	99.	100.	100.	98.	100.	99.
INTAKE AIR (RF)	DEG F	86.	73.	85.	89.	74.	86.	85.	76.	85.
INTAKE AIR (RR)	DEG F	86.	72.	85.	89.	74.	85.	85.	75.	85.
INTAKE AIR (LF)	DEG F	84.	67.	78.	87.	71.	78.	86.	73.	78.
INTAKE AIR (LR)	DEG F	85.	68.	76.	88.	71.	78.	86.	72.	78.
HP AIR (RF)	DEG F	107.	92.	104.	110.	93.	104.	106.	95.	104.
HP AIR (RR)	DEG F	108.	92.	104.	110.	93.	105.	106.	95.	104.
HP AIR (LF)	DEG F	108.	90.	100.	110.	94.	100.	108.	95.	100.
HP AIR (LR)	DEG F	107.	89.	97.	110.	93.	98.	109.	93.	98.
EXH. STACK	DEG F	449.	464.	474.	447.	458.	466.	443.	454.	461.
WATER INLET	DEG F	76.	65.	72.	85.	68.	75.	85.	73.	79.
CELL AIR	DEG F	84.	66.	74.	86.	70.	76.	86.	70.	76.
EXHAUST 1R	DEG F	489.	473.	483.	487.	471.	477.	485.	469.	473.
EXHAUST 2R	DEG F	462.	450.	457.	460.	446.	450.	459.	446.	446.
EXHAUST 3R	DEG F	467.	447.	453.	463.	442.	447.	458.	439.	441.
EXHAUST 4R	DEG F	476.	460.	470.	470.	455.	461.	466.	451.	452.
EXHAUST 5R	DEG F	460.	440.	452.	460.	438.	445.	460.	438.	442.
EXHAUST 6R	DEG F	472.	449.	460.	467.	449.	453.	466.	444.	443.
EXHAUST 1L	DEG F	506.	523.	533.	505.	519.	523.	505.	515.	515.
EXHAUST 2L	DEG F	501.	518.	531.	502.	516.	525.	499.	510.	517.
EXHAUST 3L	DEG F	469.	482.	500.	469.	478.	491.	466.	476.	484.
EXHAUST 4L	DEG F	497.	519.	481.	499.	516.	477.	495.	512.	469.
EXHAUST 5L	DEG F	515.	534.	544.	512.	525.	534.	504.	520.	528.
EXHAUST 6L	DEG F	527.	547.	559.	526.	539.	548.	518.	533.	538.
OIL PRESSURE	PSI	35.0	34.0	34.0	35.0	34.0	35.0	34.0	34.0	34.0
FUEL SPILL	PSI	36.0	35.0	35.0	37.0	35.0	35.0	37.0	35.0	35.0
BOOST (RF)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (RR)	PSI	2.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AIR BOX	PSI	4.0	10.0	10.0	5.0	10.0	10.0	5.0	9.0	10.0
INLET VAC. (RF)	IN-H2O	1.6	1.5	1.5	1.6	1.5	1.5	1.5	1.5	1.5
INLET VAC. (RR)	IN-H2O	1.7	1.5	1.6	1.5	1.4	1.6	1.5	1.5	1.6
INLET VAC. (LF)	IN-H2O	4.0	3.9	4.0	4.1	3.8	4.1	4.0	3.9	4.0
INLET VAC. (LR)	IN-H2O	4.0	3.8	4.0	4.0	3.9	4.0	3.8	3.9	4.0
EXH. PRESS. (R)	PSI	0.0	.1	0.0	0.0	.1	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	5.7	3.2	3.1	3.7	3.2	3.2	3.7	3.1	3.1
TURB. IN. (RR)	IN-HG	5.7	3.1	3.1	3.7	3.0	3.1	3.5	3.1	3.0
TURB. IN. (LF)	IN-HG	5.9	3.1	3.0	3.7	3.1	3.0	3.5	3.1	3.0
TURB. IN. (LR)	IN-HG	5.7	3.3	3.2	3.7	3.3	3.2	3.7	3.3	3.1
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.5	3.0	3.0	3.6	3.0	3.0	3.7	3.7	3.3
WATER PRESS.	PSI	55.	50.	50.	55.	50.	50.	6.	50.	50.

TABLE C-24. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1000 RPM, 20, 25% WATER

DYNAMOMETER CONSTANT: 2000.   API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		23.	55.	69.	24.	56.	70.
NOM. WATER PCT.		20.	20.	20.	25.	25.	25.
ENGINE SPEED	RPM	1000.	1000.	1000.	1000.	1000.	1000.
OBS. TORQUE	LB-FT	877.	877.	877.	877.	877.	877.
BAR. PRESS.	IN-HG	29.29	29.21	29.09	29.27	29.18	29.04
DRY BULB	DEG F	72.	69.	72.	72.	69.	72.
WET BULB	DEG F	66.	60.	66.	66.	60.	66.
REL. HUMIDITY	PCT	73.	59.	73.	73.	59.	73.
CORR. BHP	HP	167.6	165.0	167.9	167.7	165.2	168.2
CORR. BMEP	PSI	37.1	36.5	37.2	37.1	36.6	37.3
FUEL FLOW	LB/HR	73.83	73.68	73.02	73.91	73.77	73.53
WATER FLOW	CC/MIN	159.0	155.9	155.9	208.0	208.0	211.0
CALC. VOL. %	PCT.	19.3	19.1	19.2	23.9	23.9	24.2
BSFC	LB/BHP-HR	.4405	.4466	.4349	.4407	.4467	.4372
AIR FLOW L	LB/MIN	40.1	40.8	40.1	39.9	41.0	40.0
AIR FLOW R	LB/MIN	40.3	41.5	39.7	40.3	41.2	40.2
COOLANT IN	DEG F	179.	176.	177.	179.	177.	176.
COOLANT OUT	DEG F	185.	182.	184.	185.	184.	183.
OIL SUMP	DEG F	201.	198.	200.	202.	200.	200.
FUEL IN	DEG F	96.	96.	97.	95.	94.	96.
FUEL RETURN	DEG F	115.	114.	115.	114.	112.	114.
FUEL SUPPLY	DEG F	88.	88.	86.	87.	90.	87.
FUEL COOLER	DEG F	96.	97.	97.	96.	93.	96.
INTAKE AIR (RF)	DEG F	87.	77.	87.	86.	79.	87.
INTAKE AIR (RR)	DEG F	87.	76.	86.	85.	78.	86.
INTAKE AIR (LF)	DEG F	80.	73.	78.	81.	73.	80.
INTAKE AIR (LR)	DEG F	81.	72.	77.	82.	73.	79.
HP AIR (RF)	DEG F	109.	95.	106.	106.	97.	105.
HP AIR (RR)	DEG F	109.	95.	106.	107.	97.	106.
HP AIR (LF)	DEG F	104.	95.	99.	104.	95.	102.
HP AIR (LR)	DEG F	104.	93.	97.	103.	93.	99.
EXH. STACK	DEG F	439.	446.	456.	430.	443.	450.
WATER INLET	DEG F	85.	75.	79.	83.	76.	81.
CELL AIR	DEG F	80.	70.	76.	80.	70.	76.
EXHAUST 1R	DEG F	476.	463.	471.	471.	463.	465.
EXHAUST 2R	DEG F	453.	447.	450.	451.	447.	451.
EXHAUST 3R	DEG F	453.	432.	443.	455.	433.	443.
EXHAUST 4R	DEG F	456.	445.	451.	458.	447.	453.
EXHAUST 5R	DEG F	451.	432.	441.	453.	433.	442.
EXHAUST 6R	DEG F	458.	435.	443.	463.	439.	446.
EXHAUST 1L	DEG F	495.	505.	510.	489.	500.	504.
EXHAUST 2L	DEG F	487.	500.	509.	483.	495.	504.
EXHAUST 3L	DEG F	456.	469.	482.	445.	466.	476.
EXHAUST 4L	DEG F	487.	502.	464.	482.	496.	461.
EXHAUST 5L	DEG F	492.	505.	516.	487.	50.	510
EXHAUST 6L	DEG F	509.	521.	531.	507.	515.	523
OIL PRESSURE	PSI	35.0	35.0	34.0	35.0	35.0	34.0
FUEL SPILL	PSI	38.0	35.0	35.0	38.0	36.0	36.0
BOOST (RF)	PSI	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (RR)	PSI	2.0	0.0	0.0	2.0	0.0	0.0
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0
AIR BOX	PSI	5.0	10.0	10.0	5.0	10.0	10.0
INLET VAC. (RF)	IN-H2O	1.5	1.5	1.6	1.5	1.5	1.6
INLET VAC. (RR)	IN-H2O	1.6	1.5	1.6	1.6	1.6	1.6
INLET VAC. (LF)	IN-H2O	3.9	4.0	4.1	3.9	3.9	4.0
INLET VAC. (LR)	IN-H2O	3.9	3.9	4.0	3.8	3.9	4.0
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	3.1	3.1	3.0	3.3	3.1	3.1
TURB. IN. (RR)	IN-HG	3.1	3.1	3.0	3.3	3.1	3.0
TURB. IN. (LF)	IN-HG	2.9	3.1	3.1	3.3	3.1	3.0
TURB. IN. (LR)	IN-HG	2.9	3.2	3.1	3.3	3.2	3.1
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.5	4.0	3.9	4.5	4.2	4.0
WATER PRESS.	PSI	55.	50.	50.	55.	50.	50.

TABLE C-25. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1000 RPM, FUEL INJECTION TIMING RETARDED 2.4 DEGREES

DYNAMOMETER CONSTANT: 2000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		72.	78.	73.	74.	75.	76.	77.
NOM. WATER PCT.		0.	0.	5.	10.	15.	20.	25.
ENGINE SPEED	RPM	1000.	1000.	1000.	1000.	1000.	1000.	1000.
OBS. TORQUE	LB-FT	877.	877.	877.	877.	877.	877.	877.
BAR. PRESS.	IN-HG	29.23	29.21	29.25	29.25	29.24	29.32	29.23
DRY BULB	DEG F	74.	82.	74.	80.	80.	85.	89.
WET BULB	DEG F	62.	60.	62.	61.	61.	61.	61.
REL. HUMIDITY	PCT	51.	26.	51.	32.	32.	32.	32.
CORR. BHP	HP	166.2	166.8	166.5	166.4	166.7	166.4	166.5
CORR. BMEP	PSI	36.8	36.9	36.9	36.9	36.9	36.9	36.9
FUEL FLOW	LB/HR	72.29	72.23	71.72	72.17	72.32	72.64	73.22
WATER FLOW	CC/MIN	0.0	0.0	32.3	68.1	109.5	157.4	208.0
CALC. VOL. %	PCT	0.0	0.0	4.8	9.5	14.4	19.4	24.0
BSFC	LB/BHP-HR	.4349	.4331	.4307	.4337	.4339	.4365	.4397
AIR FLOW L	LB/MIN	40.8	40.1	40.4	40.4	40.3	40.3	40.4
AIR FLOW R	LB/MIN	40.8	40.7	40.7	40.5	40.7	40.4	40.5
COOLANT IN	DEG F	176.	178.	177.	177.	176.	179.	179.
COOLANT OUT	DEG F	183.	184.	184.	183.	183.	185.	185.
OIL SUMP	DEG F	195.	200.	198.	198.	198.	200.	201.
FUEL IN	DEG F	97.	100.	99.	100.	97.	97.	95.
FUEL RETURN	DEG F	117.	122.	119.	119.	116.	116.	114.
FUEL SUPPLY	DEG F	88.	101.	90.	90.	90.	90.	90.
FUEL COOLER	DEG F	97.	98.	99.	99.	97.	96.	96.
INTAKE AIR (RF)	DEG F	86.	93.	90.	92.	93.	95.	95.
INTAKE AIR (RR)	DEG F	86.	93.	90.	93.	92.	94.	95.
INTAKE AIR (LF)	DEG F	79.	85.	81.	83.	84.	85.	84.
INTAKE AIR (LR)	DEG F	78.	86.	80.	83.	84.	86.	84.
HP AIR (RF)	DEG F	106.	112.	109.	111.	111.	112.	113.
HP AIR (RR)	DEG F	107.	113.	109.	112.	112.	113.	114.
HP AIR (LF)	DEG F	101.	108.	102.	105.	106.	108.	106.
HP AIR (LR)	DEG F	99.	107.	101.	103.	104.	106.	104.
EXH. STACK	DEG F	480.	487.	477.	473.	466.	462.	456.
WATER INLET	DEG F	78.	87.	77.	84.	85.	84.	84.
CELL AIR	DEG F	76.	82.	78.	80.	81.	82.	80.
EXHAUST 1R	DEG F	488.	489.	480.	478.	471.	472.	465.
EXHAUST 2R	DEG F	466.	468.	456.	452.	451.	452.	452.
EXHAUST 3R	DEG F	461.	462.	451.	448.	443.	442.	443.
EXHAUST 4R	DEG F	480.	478.	470.	462.	455.	457.	453.
EXHAUST 5R	DEG F	460.	460.	453.	450.	445.	445.	443.
EXHAUST 6R	DEG F	465.	466.	459.	454.	448.	447.	447.
EXHAUST 1L	DEG F	533.	533.	528.	522.	516.	509.	503.
EXHAUST 2L	DEG F	533.	538.	530.	527.	519.	513.	505.
EXHAUST 3L	DEG F	510.	512.	503.	496.	490.	485.	477.
EXHAUST 4L	DEG F	534.	539.	532.	525.	518.	512.	502.
EXHAUST 5L	DEG F	551.	559.	545.	538.	530.	524.	514.
EXHAUST 6L	DEG F	568.	573.	556.	547.	540.	534.	525.
OIL PRESSURE	PSI	36.0	35.0	35.0	35.0	35.0	34.0	34.0
FUEL SPILL	PSI	35.0	34.0	35.0	34.0	34.0	34.0	35.0
BOOST (RF)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (RR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AIR BOX	PSI	2.4	2.0	2.0	2.2	2.3	2.0	2.0
INLET VAC. (RF)	IN-H2O	1.5	1.5	1.5	1.5	1.5	1.5	1.6
INLET VAC. (RR)	IN-H2O	1.5	1.6	1.5	1.5	1.5	1.5	1.5
INLET VAC. (LF)	IN-H2O	4.0	4.1	4.0	4.1	4.0	4.0	3.9
INLET VAC. (LR)	IN-H2O	4.0	4.0	4.0	4.0	4.0	4.0	4.0
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	3.1	3.1	3.1	3.1	3.0	3.1	3.0
TURB. IN. (RR)	IN-HG	3.1	3.1	3.1	3.1	3.0	3.0	3.0
TURB. IN. (LF)	IN-HG	3.1	3.1	3.0	3.0	3.0	3.0	3.0
TURB. IN. (LR)	IN-HG	3.2	3.2	3.2	3.1	3.1	3.1	3.1
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.0	3.0	3.0	3.5	3.5	3.6	3.5
WATER PRESS.	PSI	0.	0.	50.	50.	50.	50.	50.

TABLE C-26. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1000 RPM, FUEL INJECTION TIMING RETARDED 4.1 DEGREES

DYNAMOMETER CONSTANT: 2000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		79.	85.	80.	81.	82.	83.	84.
NOM WATER PCT		0.	0.	5.	10.	15.	20.	25.
ENGINE SPEED	RPM	1000.	1000.	1000.	1000.	1000.	1000.	1000.
OBS TORQUE	LB-FT	877.	877.	877.	877.	877.	877.	877.
BAR. PRESS.	IN-HG	29.04	28.93	29.06	29.06	29.03	29.00	28.96
DRY BULB	DEG F	80.	94.	80.	83.	83.	84.	92.
WET BULB	DEG F	70.	70.	70.	71.	71.	71.	71.
REL. HUMIDITY	PCT	61.	30.	61.	56.	56.	53.	35.
CORR. BHP	HP	170.3	172.6	170.6	170.6	171.2	172.6	172.8
CORR. BMEP	PSI	37.7	38.2	37.8	37.8	37.9	38.2	38.3
FUEL FLOW	LB/HR	72.58	72.52	72.09	72.93	73.51	73.82	74.57
WATER FLOW	CC/MIN	0.0	0.0	33.8	69.7	108.0	154.4	211.7
CALC. VOL. %	PCT.	0.0	0.0	4.9	9.6	14.0	18.8	23.9
BSFC	LB/BHP-HR	.4263	.4201	.4226	.4275	.4293	.4276	.4315
AIR FLOW L	LB/MIN	39.3	39.6	39.1	39.1	40.7	38.0	39.6
AIR FLOW R	LB/MIN	40.4	39.5	39.8	39.8	39.7	39.5	39.5
COOLANT IN	DEG F	178.	177.	178.	177.	178.	177.	177.
COOLANT OUT	DEG F	184.	184.	184.	184.	184.	184.	184.
OIL SUMP	DEG F	197.	199.	198.	199.	200.	199.	200.
FUEL IN	DEG F	104.	108.	105.	107.	107.	105.	104.
FUEL RETURN	DEG F	123.	127.	124.	125.	124.	122.	121.
FUEL SUPPLY	DEG F	95.	108.	97.	99.	101.	103.	104.
FUEL COOLER	DEG F	103.	106.	105.	106.	106.	104.	104.
INTAKE AIR (RF)	DEG F	89.	100.	92.	95.	95.	100.	101.
INTAKE AIR (RR)	DEG F	89.	100.	92.	95.	95.	100.	101.
INTAKE AIR (LF)	DEG F	85.	100.	86.	88.	93.	95.	96.
INTAKE AIR (LR)	DEG F	85.	100.	86.	88.	93.	96.	97.
HP AIR (RF)	DEG F	109.	120.	112.	114.	113.	118.	120.
HP AIR (RR)	DEG F	109.	121.	112.	115.	114.	119.	120.
HP AIR (LF)	DEG F	109.	124.	110.	111.	116.	120.	119.
HP AIR (LR)	DEG F	106.	121.	108.	109.	114.	116.	117.
EXH. STACK	DEG F	493.	504.	492.	483.	480.	473.	469.
WATER INLET	DEG F	82.	99.	83.	88.	92.	95.	94.
CELL AIR	DEG F	84.	96.	86.	86.	88.	94.	96.
EXHAUST 1R	DEG F	500.	505.	494.	490.	484.	482.	479.
EXHAUST 2R	DEG F	477.	480.	468.	463.	464.	464.	464.
EXHAUST 3R	DEG F	467.	472.	463.	457.	451.	451.	453.
EXHAUST 4R	DEG F	484.	487.	480.	470.	465.	464.	464.
EXHAUST 5R	DEG F	466.	469.	461.	456.	453.	450.	450.
EXHAUST 6R	DEG F	473.	476.	467.	461.	453.	450.	452.
EXHAUST 1L	DEG F	544.	552.	542.	536.	530.	523.	520.
EXHAUST 2L	DEG F	549.	554.	544.	539.	533.	523.	518.
EXHAUST 3L	DEG F	522.	525.	513.	505.	502.	496.	489.
EXHAUST 4L	DEG F	547.	548.	542.	533.	528.	518.	512.
EXHAUST 5L	DEG F	572.	578.	567.	554.	547.	537.	530.
EXHAUST 6L	DEG F	584.	592.	579.	566.	558.	549.	543.
OIL PRESSURE	PSI	35.0	35.0	35.0	35.0	35.0	35.0	35.0
FUEL SPILL	PSI	35.0	35.0	35.0	35.0	35.0	35.0	35.0
BOOST (RF)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (RR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AIR BOX	PSI	2.0	2.0	2.0	2.0	2.0	2.0	2.0
INLET VAC. (RF)	IN-H2O	1.5	1.5	1.5	1.5	1.5	1.5	1.5
INLET VAC. (RR)	IN-H2O	1.5	1.5	1.5	1.6	1.5	1.6	1.6
INLET VAC. (LF)	IN-H2O	4.1	4.2	4.2	4.2	4.2	4.2	4.2
INLET VAC. (LR)	IN-H2O	4.1	4.2	4.0	4.1	4.1	4.1	4.1
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	3.1	3.1	3.1	3.1	3.1	3.0	3.0
TURB. IN. (RR)	IN-HG	3.1	3.1	3.1	3.1	3.1	3.0	3.0
TURB. IN. (LF)	IN-HG	3.0	3.0	3.0	3.0	3.0	3.0	3.0
TURB. IN. (LR)	IN-HG	3.2	3.2	3.2	3.2	3.2	3.1	3.1
FUEL PRESS.	PSI	30.0	26.0	25.0	26.0	26.0	26.0	26.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.0	3.8	3.2	3.2	3.5	3.6	3.7
WATER PRESS.	PSI	0.	0.	50.	0.	50.	50.	50.

TABLE C-27. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1000 RPM, FUEL INJECTION TIMING ADVANCED 2.8 DEGREES

DYNAMOMETER CONSTANT: 2000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		93.	99.	94.	95.	96.	97.	98.
NOM. WATER PCT.		0.	0.	5.	10.	15.	20.	25.
ENGINE SPEED	RPM	1000.	1000.	1000.	1000.	1000.	1000.	1000
OBS. TORQUE	LB-FT	877.	877.	877.	877.	877.	877.	877.
BAR. PRESS.	IN-HG	29.24	29.04	29.22	29.20	29.16	29.12	29.09
DRY BULB	DEG F	72.	85.	72.	80.	80.	84.	84.
WET BULB	DEG F	60.	65.	60.	61.	61.	64.	64.
REL. HUMIDITY	PCT	49.	33.	49.	32.	32.	33.	33.
CORR. BHP	HP	165.1	169.8	166.0	166.5	167.4	168.7	168.9
CORR. BMEP	PSI	36.6	37.6	36.8	36.9	37.1	37.4	37.4
FUEL FLOW	LB/HR	72.32	71.68	72.35	72.91	73.59	74.10	74.60
WATER FLOW	CC/MIN	0.0	0.0	30.8	68.1	111.0	157.4	208.0
CALC. VOL. %	PCT.	0.0	0.0	4.5	9.4	14.3	19.1	23.7
BSFC	LB/BHP-HR	.4382	.4222	.4357	.4380	.4397	.4392	.4416
AIR FLOW L	LB/MIN	41.0	39.0	40.9	40.5	40.0	39.4	39.4
AIR FLOW R	LB/MIN	40.7	39.2	40.3	40.5	39.8	39.6	39.8
COOLANT IN	DEG F	177.	176.	177.	178.	178.	179.	178.
COOLANT OUT	DEG F	183.	183.	184.	185.	185.	185.	185.
OIL SUMP	DEG F	198.	199.	198.	201.	202.	202.	202.
FUEL IN	DEG F	96.	104.	101.	100.	102.	100.	99.
FUEL RETURN	DEG F	118.	124.	121.	120.	120.	118.	118.
FUEL SUPPLY	DEG F	84.	95.	89.	90.	92.	93.	94.
FUEL COOLER	DEG F	96.	103.	99.	100.	101.	100.	99.
INTAKE AIR (RF)	DEG F	85.	95.	88.	89.	92.	90.	92.
INTAKE AIR (RR)	DEG F	84.	95.	87.	89.	92.	90.	92.
INTAKE AIR (LF)	DEG F	75.	91.	80.	82.	84.	88.	90.
INTAKE AIR (LR)	DEG F	75.	92.	80.	82.	85.	89.	90.
HP AIR (RF)	DEG F	104.	114.	106.	109.	110.	110.	112.
HP AIR (RR)	DEG F	104.	114.	107.	109.	110.	111.	112.
HP AIR (LF)	DEG F	97.	114.	102.	104.	107.	110.	112.
HP AIR (LR)	DEG F	96.	112.	101.	103.	106.	109.	111.
EXH. STACK	DEG F	471.	416.	469.	467.	463.	456.	451.
WATER INLET	DEG F	72.	90.	76.	84.	87.	88.	89.
CELL AIR	DEG F	72.	88.	76.	79.	82.	86.	86.
EXHAUST 1R	DEG F	483.	485.	482.	476.	474.	473.	467.
EXHAUST 2R	DEG F	460.	462.	456.	451.	455.	456.	455.
EXHAUST 3R	DEG F	451.	452.	451.	452.	446.	446.	447.
EXHAUST 4R	DEG F	463.	466.	461.	457.	452.	453.	453.
EXHAUST 5R	DEG F	448.	451.	447.	446.	443.	442.	443.
EXHAUST 6R	DEG F	456.	455.	453.	450.	445.	443.	448.
EXHAUST 1L	DEG F	525.	527.	523.	519.	515.	510.	506.
EXHAUST 2L	DEG F	525.	524.	524.	520.	514.	507.	502.
EXHAUST 3L	DEG F	494.	497.	485.	482.	480.	481.	471.
EXHAUST 4L	DEG F	526.	533.	524.	520.	514.	506.	501.
EXHAUST 5L	DEG F	541.	545.	535.	533.	521.	515.	508.
EXHAUST 6L	DEG F	561.	567.	556.	548.	544.	536.	525.
OIL PRESSURE	PSI	34.0	34.0	34.0	34.0	34.0	34.0	34.0
FUEL SPILL	PSI	34.0	33.0	34.0	34.0	34.0	34.0	34.0
BOOST (RF)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (RR)	PSI	0.0	1.0	0.0	0.0	0.0	0.0	0.0
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AIR BOX	PSI	2.0	2.0	2.0	2.0	2.0	2.0	2.0
INLET VAC. (RF)	IN-H2O	1.5	1.5	1.5	1.5	1.5	1.5	1.5
INLET VAC. (RR)	IN-H2O	1.5	1.5	1.5	1.5	1.6	1.5	1.6
INLET VAC. (LF)	IN-H2O	4.0	4.1	4.0	4.0	3.9	4.0	4.0
INLET VAC. (LR)	IN-H2O	3.9	4.1	4.0	4.0	4.0	4.0	4.0
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	3.2	3.0	3.1	3.1	3.1	3.0	3.1
TURB. IN. (RR)	IN-HG	3.1	3.0	3.0	3.0	3.0	3.0	3.0
TURB. IN. (LF)	IN-HG	3.1	3.0	3.0	3.0	3.0	3.0	3.0
TURB. IN. (LR)	IN-HG	3.2	3.1	3.1	3.2	3.1	3.1	3.1
FUEL PRESS.	PSI	22.0	20.0	22.0	22.0	22.0	22.0	22.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.2	3.0	3.4	35.0	3.5	3.6	3.7
WATER PRESS.	PSI	0.	0.	50.	50.	50.	50.	50.

TABLE C-28. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1000 RPM, FUEL INJECTION TIMING ADVANCED 5.5 DEGREES

DYNAMOMETER CONSTANT: 2000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		100.	106.	101.	102.	103.	104.	105.
NOM. WATER PCT.		0.	0.	5.	10.	15.	20.	25.
ENGINE SPEED	RPM	1000.	1000.	1000.	1000.	1000.	1000.	1000.
OBS. TORQUE	LB-FT	877.	877.	877.	877.	877.	877.	877.
BAR. PRESS.	IN-HG	28.98	28.95	28.99	29.00	29.00	28.99	28.97
DRY BULB	DEG F	75.	82.	75.	75.	82.	82.	82.
WET BULB	DEG F	69.	70.	69.	70.	70.	70.	70.
REL. HUMIDITY	PCT	74.	55.	74.	78.	55.	55.	55.
CORR. BHP	HP	169.4	171.5	170.2	169.9	170.8	170.6	171.0
CORR. BMEP	PSI	37.5	38.0	37.7	37.6	37.8	37.8	37.9
FUEL FLOW	LB/HR	73.41	72.85	73.77	74.04	75.47	76.11	76.50
WATER FLOW	CC/MIN	0.0	0.0	32.3	68.1	112.5	160.6	215.5
CALC. VOL. %	PCT.	0.0	0.0	4.6	9.3	14.2	19.0	23.8
BSFC	LB/BHP-HR	.4333	.4247	.4334	.4357	.4419	.4460	.4474
AIR FLOW L	LB/MIN	40.0	38.7	39.5	39.7	40.9	39.2	39.0
AIR FLOW R	LB/MIN	40.1	39.2	39.9	40.2	39.8	39.9	40.1
COOLANT IN	DEG F	177.	179.	178.	178.	178.	178.	178.
COOLANT OUT	DEG F	184.	186.	185.	184.	185.	185.	185.
OIL SUMP	DEG F	200.	202.	202.	201.	203.	203.	204.
FUEL IN	DEG F	104.	104.	104.	103.	104.	103.	102.
FUEL RETURN	DEG F	126.	125.	125.	122.	122.	120.	119.
FUEL SUPPLY	DEG F	90.	96.	93.	91.	94.	94.	95.
FUEL COOLER	DEG F	103.	104.	104.	103.	104.	103.	102.
INTAKE AIR (RF)	DEG F	83.	90.	85.	84.	91.	89.	91.
INTAKE AIR (RR)	DEG F	83.	91.	85.	85.	91.	89.	92.
INTAKE AIR (LF)	DEG F	79.	93.	82.	87.	91.	89.	92.
INTAKE AIR (LR)	DEG F	78.	94.	81.	87.	92.	89.	93.
HP AIR (RF)	DEG F	101.	110.	104.	103.	110.	108.	110.
HP AIR (RR)	DEG F	103.	112.	105.	104.	111.	109.	112.
HP AIR (LF)	DEG F	101.	112.	104.	108.	112.	110.	113.
HP AIR (LR)	DEG F	99.	114.	102.	107.	112.	110.	113.
EXH. STACK	DEG F	469.	474.	466.	462.	462.	453.	451.
WATER INLET	DEG F	78.	88.	79.	83.	88.	88.	89.
CELL AIR	DEG F	78.	88.	82.	80.	86.	85.	86.
EXHAUST 1R	DEG F	486.	494.	477.	476.	476.	475.	471.
EXHAUST 2R	DEG F	465.	470.	460.	457.	464.	465.	464.
EXHAUST 3R	DEG F	459.	461.	457.	452.	452.	453.	456.
EXHAUST 4R	DEG F	461.	468.	460.	456.	454.	457.	451.
EXHAUST 5R	DEG F	449.	453.	444.	446.	446.	445.	446.
EXHAUST 6R	DEG F	455.	459.	451.	447.	443.	446.	448.
EXHAUST 1L	DEG F	522.	536.	520.	517.	513.	508.	505.
EXHAUST 2L	DEG F	518.	530.	521.	517.	512.	506.	503.
EXHAUST 3L	DEG F	498.	506.	494.	490.	488.	483.	477.
EXHAUST 4L	DEG F	523.	529.	521.	518.	516.	508.	502.
EXHAUST 5L	DEG F	536.	538.	532.	526.	521.	512.	509.
EXHAUST 6L	DEG F	557.	557.	550.	543.	540.	530.	527.
OIL PRESSURE	PSI	35.0	34.0	34.0	34.0	34.0	34.0	34.0
FUEL SPILL	PSI	34.0	34.0	34.0	34.0	34.0	34.0	34.0
BOOST (RF)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (RR)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AIR BOX	PSI	2.0	2.0	2.0	2.0	2.0	2.0	2.0
INLET VAC. (RF)	IN-H2O	1.5	1.5	1.5	1.5	1.5	1.5	1.5
INLET VAC. (RR)	IN-H2O	1.5	1.5	1.5	1.5	1.5	1.5	1.6
INLET VAC. (LF)	IN-H2O	4.1	4.0	4.1	4.0	4.1	4.1	4.1
INLET VAC. (LR)	IN-H2O	4.0	4.0	4.0	4.0	4.0	4.0	4.0
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	3.1	3.0	3.1	3.1	3.1	3.1	3.0
TURB. IN. (RR)	IN-HG	3.0	3.0	3.0	3.0	3.0	3.0	3.0
TURB. IN. (LF)	IN-HG	3.1	3.0	3.0	3.0	3.0	3.0	3.1
TURB. IN. (LR)	IN-HG	3.1	3.1	3.1	3.1	3.1	3.1	3.1
FUEL PRESS.	PSI	25.0	20.0	25.0	24.0	24.0	24.0	24.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.0	3.2	30.0	3.0	3.2	3.4	3.5
WATER PRESS.	PSI	0.	0.	50.	50.	50.	50.	50.

TABLE C-29. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1200 RPM, BASELINE

DYNAMOMETER CONSTANT: 2000 API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		4.	10.	16.	26.	32.
NOM. WATER PCT.		0.	0.	0.	0.	0.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	1229.	1229.	1229.	1229.	1229.
BAR. PRESS.	IN-HG	29.16	29.25	28.96	29.31	29.18
DRY BULB	DEG F	75.	72.	75.	79.	72.
WET BULB	DEG F	65.	64.	70.	61.	62.
REL. HUMIDITY	PCT	59.	65.	78.	34.	57.
CORR. BHP	HP	281.3	280.1	286.1	277.9	282.4
CORR. BMEP	PSI	51.9	51.7	52.8	51.3	52.1
FUEL FLOW	LB/HR	115.57	115.85	115.13	115.76	115.11
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	0.0
BSFC	LB/BHP-HR	.4108	.4136	.4023	.4166	.4077
AIR FLOW L	LB/MIN	52.1	50.5	49.1	50.8	49.4
AIR FLOW R	LB/MIN	51.8	52.9	50.2	52.3	52.2
COOLANT IN	DEG F	180.	179.	181.	180.	177.
COOLANT OUT	DEG F	188.	187.	189.	188.	185.
OIL SUMP	DEG F	206.	206.	207.	204.	204.
FUEL IN	DEG F	102.	101.	102.	101.	99.
FUEL RETURN	DEG F	125.	123.	124.	122.	122.
FUEL SUPPLY	DEG F	85.	83.	83.	79.	81.
FUEL COOLER	DEG F	101.	100.	101.	107.	100.
INTAKE AIR (RF)	DEG F	85.	91.	84.	88.	90.
INTAKE AIR (RR)	DEG F	86.	91.	84.	87.	89.
INTAKE AIR (LF)	DEG F	83.	80.	84.	78.	85.
INTAKE AIR (LR)	DEG F	84.	80.	84.	78.	85.
HP AIR (RF)	DEG F	122.	127.	121.	123.	125.
HP AIR (RR)	DEG F	123.	129.	121.	123.	126.
HP AIR (LF)	DEG F	122.	120.	124.	117.	125.
HP AIR (LR)	DEG F	122.	119.	121.	116.	123.
EXH. STACK	DEG F	537.	545.	548.	545.	553.
WATER INLET	DEG F	78.	78.	78.	69.	82.
CELL AIR	DEG F	77.	76.	80.	76.	82.
EXHAUST 1R	DEG F	586.	598.	605.	607.	606.
EXHAUST 2R	DEG F	567.	573.	578.	583.	582.
EXHAUST 3R	DEG F	587.	588.	593.	594.	594.
EXHAUST 4R	DEG F	598.	603.	607.	595.	599.
EXHAUST 5R	DEG F	578.	585.	587.	582.	584.
EXHAUST 6R	DEG F	568.	573.	580.	585.	585.
EXHAUST 1L	DEG F	611.	620.	621.	614.	616.
EXHAUST 2L	DEG F	624.	628.	631.	638.	643.
EXHAUST 3L	DEG F	585.	591.	595.	590.	594.
EXHAUST 4L	DEG F	628.	638.	638.	634.	639.
EXHAUST 5L	DEG F	628.	636.	640.	630.	637.
EXHAUST 6L	DEG F	640.	649.	648.	645.	649.
OIL PRESSURE	PSI	42.0	43.0	42.0	43.0	42.0
FUEL SPILL	PSI	46.0	45.0	45.0	45.0	45.0
BOOST (RF)	PSI	2.0	2.0	2.1	2.0	2.0
BOOST (RR)	PSI	1.2	1.5	1.0	1.0	1.0
BOOST (LF)	PSI	1.0	1.5	1.0	1.0	1.0
BOOST (LR)	PSI	2.5	2.5	2.5	2.0	2.0
AIR BOX	PSI	2.0	5.0	6.0	7.0	7.0
INLET VAC. (RF)	IN-H2O	2.6	2.7	2.5	2.6	2.5
INLET VAC. (RR)	IN-H2O	2.7	2.7	2.7	2.7	2.7
INLET VAC. (LF)	IN-H2O	5.6	5.6	5.6	5.7	5.7
INLET VAC. (LR)	IN-H2O	5.4	5.5	5.5	5.5	5.6
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	0.0	2.4	3.3	2.4	3.7
TURB. IN. (RR)	IN-HG	0.0	2.4	3.3	2.4	3.7
TURB. IN. (LF)	IN-HG	0.0	2.4	2.9	2.4	3.7
TURB. IN. (LR)	IN-HG	0.0	2.4	2.9	2.4	3.7
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	4.2	3.1	3.5	3.2	3.0
WATER PRESS.	PSI	0.	0.	0.	0.	0.

TABLE C-30. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1200 RPM, WITH WATER ADDITION

DYNAMOMETER CONSTANT: 8000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		27.	28.	29.	30.	31.
NOM. WATER PCT.		5.	10.	15.	20.	25.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	1229.	1229.	1229.	1229.	1229.
BAR. PRESS.	IN-HG	29.31	29.29	29.25	29.20	29.18
DRY BULB	DEG F	79.	72.	72.	75.	72.
WET BULB	DEG F	61.	62.	62.	64.	62.
REL. HUMIDITY	PCT	34.	57.	57.	55.	57.
CORR. BHP	HP	280.0	280.5	280.9	283.2	282.4
CORR. BMEP	PSI	51.7	51.8	51.9	52.3	52.1
FUEL FLOW	LB/HR	116.26	115.70	116.43	116.22	116.43
WATER FLOW	CC/MIN	49.8	114.0	175.1	215.5	366.4
CALC. VOL. %	PCT.	4.5	9.9	14.3	17.1	25.9
BSFC	LB/BHP-HR	.4152	.4124	.4144	.4104	.4123
AIR FLOW L	LB/MIN	50.7	50.9	50.8	51.0	49.4
AIR FLOW R	LB/MIN	51.6	51.8	51.6	51.1	51.2
COOLANT IN	DEG F	179.	179.	179.	179.	178.
COOLANT OUT	DEG F	186.	186.	187.	187.	185.
OIL SUMP	DEG F	206.	206.	206.	206.	206.
FUEL IN	DEG F	102.	102.	103.	101.	95.
FUEL RETURN	DEG F	123.	123.	122.	119.	115.
FUEL SUPPLY	DEG F	84.	84.	82	82.	82.
FUEL COOLER	DEG F	102.	104.	104.	105.	100.
INTAKE AIR (RF)	DEG F	93.	88.	87.	88.	90.
INTAKE AIR (RR)	DEG F	92.	87.	86.	88.	89.
INTAKE AIR (LF)	DEG F	84.	84.	84.	84.	85.
INTAKE AIR (LR)	DEG F	84.	84.	83.	84.	86.
HP AIR (RF)	DEG F	128.	122.	122.	123.	123.
HP AIR (RR)	DEG F	129.	123.	123.	124.	124.
HP AIR (LF)	DEG F	122.	122.	122.	122.	122.
HP AIR (LR)	DEG F	121.	121.	119.	120.	122.
EXH. STACK	DEG F	545.	536.	531.	525.	519.
WATER INLET	DEG F	70.	80.	84.	84.	84.
CELL AIR	DEG F	82.	80.	80.	84.	82.
EXHAUST 1R	DEG F	599.	587.	515.	567.	561.
EXHAUST 2R	DEG F	575.	563.	554.	551.	546.
EXHAUST 3R	DEG F	590.	582.	578.	574.	564.
EXHAUST 4R	DEG F	591.	584.	577.	571.	564.
EXHAUST 5R	DEG F	584.	575.	570.	563.	557.
EXHAUST 6R	DEG F	586.	570.	564.	557.	550.
EXHAUST 1L	DEG F	606.	591.	587.	584.	579.
EXHAUST 2L	DEG F	629.	616.	611.	609.	604.
EXHAUST 3L	DEG F	588.	574.	564.	564.	557.
EXHAUST 4L	DEG F	627.	613.	607.	607.	601.
EXHAUST 5L	DEG F	626.	612.	609.	599.	588.
EXHAUST 6L	DEG F	641.	629.	622.	619.	609.
OIL PRESSURE	PSI	43.0	43.0	42.0	42.0	42.0
FUEL SPILL	PSI	45.0	45.0	44.0	44.0	43.0
BOOST (RF)	PSI	2.0	2.0	2.0	2.0	2.0
BOOST (RR)	PSI	1.0	1.5	1.5	1.5	1.5
BOOST (LF)	PSI	1.0	1.0	1.0	1.0	1.0
BOOST (LR)	PSI	2.5	2.0	2.5	2.5	2.0
AIR BOX	PSI	7.0	7.0	7.0	7.0	7.0
INLET VAC. (RF)	IN-H2O	2.6	2.6	2.6	2.5	2.5
INLET VAC. (RR)	IN-H2O	2.7	2.7	2.7	2.6	2.6
INLET VAC. (LF)	IN-H2O	5.7	5.6	5.7	5.7	5.7
INLET VAC. (LR)	IN-H2O	5.6	5.6	5.5	5.5	5.5
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	2.9	3.3	3.3	3.3	3.3
TURB. IN. (RR)	IN-HG	2.9	3.3	3.3	3.3	3.3
TURB. IN. (LF)	IN-HG	2.9	3.3	3.3	3.3	3.3
TURB. IN. (LR)	IN-HG	2.9	3.3	3.3	3.3	3.3
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.5	3.4	3.5	4.0	4.2
WATER PRESS.	PSI	50.	50.	50.	50.	50.

TABLE C-31. ENGINE TEST RESULTS. DETROIT DIESEL ENGINE, 1400 RPM, BASELINE

DYNAMOMETER CONSTANT: 2000. API GRAVITY OF DIESEL FUEL 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		5.	11.	17	33.	39	58	64
NOM. WATER PCT.		0.	0.	0.	0	0	0.	0
ENGINE SPEED	RPM	1400.	1400.	1400.	1400.	1400.	1400	1400
OBS. TORQUE	LB-FT	1654.	1654.	1654.	1654.	1654.	1654	1654
BAR. PRESS.	IN-HG	29.30	29.12	29.17	29.17	29.23	29.22	29.15
DRY BULB	DEG F	67.	74.	75.	75.	71.	65.	68
WET BULB	DEG F	62.	67.	64.	62.	59.	59.	64.
REL. HUMIDITY	PCT	76.	70.	55.	48.	49.	70.	81.
CORR. BHP	HP	435.0	446.5	444.1	442.5	437.5	431.1	438.6
CORR. BMEP	PSI	68.8	70.6	70.2	70.0	69.2	68.2	69.4
FUEL FLOW	LB/HR	177.76	177.08	177.47	176.47	177.44	176.38	176.47
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BSFC	LB/BHP-HR	.4087	.3965	.3997	.3988	.4056	.4091	.4023
AIR FLOW L	LB/MIN	66.3	64.8	66.0	66.3	66.0	66.8	64.7
AIR FLOW R	LB/MIN	68.6	67.4	68.4	69.0	69.7	69.5	68.7
COOLANT IN	DEG F	178.	179.	177.	176.	177.	179.	177.
COOLANT OUT	DEG F	187.	189.	186.	185.	185.	187.	185.
OIL SUMP	DEG F	211.	211.	209.	210.	210.	208.	209.
FUEL IN	DEG F	104.	105.	105.	104.	104.	100.	101.
FUEL RETURN	DEG F	126.	127.	126.	127.	126.	122.	123.
FUEL SUPPLY	DEG F	81.	82.	80.	81.	84.	75.	79.
FUEL COOLER	DEG F	105.	104.	106.	103.	100.	99.	99.
INTAKE AIR (RF)	DEG F	76.	94.	90.	90.	87.	82.	73.
INTAKE AIR (RR)	DEG F	77.	93.	90.	90.	85.	81.	92.
INTAKE AIR (LF)	DEG F	74.	86.	89.	85.	77.	68.	75.
INTAKE AIR (LR)	DEG F	74.	86.	89.	85.	77.	67.	73.
HP AIR (RF)	DEG F	140.	156.	153.	154.	152.	143.	153.
HP AIR (RR)	DEG F	141.	157.	154.	154.	152.	142.	152.
HP AIR (LF)	DEG F	141.	153.	157.	153.	147.	134.	139.
HP AIR (LR)	DEG F	137.	149.	153.	149.	143.	129.	134.
EXH. STACK	DEG F	617.	634.	633.	641.	636.	653.	660.
WATER INLET	DEG F	69.	75.	75.	78.	83.	67.	71.
CELL AIR	DEG F	69.	82.	82.	81.	75.	62.	70.
EXHAUST 1R	DEG F	670.	686.	694.	697.	693.	690.	695.
EXHAUST 2R	DEG F	674.	688.	693.	675.	693.	685.	690.
EXHAUST 3R	DEG F	700.	722.	723.	721.	714.	698.	713.
EXHAUST 4R	DEG F	678.	698.	701.	697.	690.	679.	691.
EXHAUST 5R	DEG F	676.	690.	694.	691.	692.	673.	687.
EXHAUST 6R	DEG F	662.	680.	680.	683.	689.	664.	678.
EXHAUST 1L	DEG F	708.	726.	730.	720.	731.	739.	747.
EXHAUST 2L	DEG F	737.	748.	751.	768.	767.	773.	779.
EXHAUST 3L	DEG F	684.	701.	702.	698.	694.	720.	732.
EXHAUST 4L	DEG F	722.	740.	742.	740.	742.	756.	771.
EXHAUST 5L	DEG F	728.	749.	753.	752.	752.	766.	779.
EXHAUST 6L	DEG F	0.	745.	748.	747.	739.	762.	777.
OIL PRESSURE	PSI	50.0	51.0	51.0	50.0	50.0	50.0	50.0
FUEL SPILL	PSI	50.0	48.0	47.0	47.0	45.0	47.0	47.0
BOOST (RF)	PSI	4.2	4.0	4.0	4.0	4.0	4.0	4.0
BOOST (RR)	PSI	3.5	3.0	3.0	3.0	3.5	3.0	3.0
BOOST (LF)	PSI	3.5	3.0	3.0	3.0	3.0	3.5	3.0
BOOST (LR)	PSI	4.5	4.0	4.0	4.5	4.5	4.0	4.0
AIR BOX	PSI	6.0	8.0	8.0	10.0	10.0	12.0	13.0
INLET VAC. (RF)	IN-H2O	4.4	4.2	4.5	4.4	4.5	4.1	4.2
INLET VAC. (RR)	IN-H2O	4.6	4.5	4.5	4.5	4.5	4.3	4.3
INLET VAC. (LF)	IN-H2O	8.2	7.8	8.1	8.5	8.3	8.3	8.3
INLET VAC. (LR)	IN-H2O	8.0	8.2	8.2	8.2	9.5	8.1	8.1
EXH. PRESS. (R)	PSI	.1	.2	.2	0.0	0.0	.1	.1
EXH. PRESS. (L)	PSI	.1	.2	.1	0.0	0.0	.1	.1
TURB. IN. (RF)	IN-HG	2.0	2.0	6.9	9.8	10.0	9.5	9.4
TURB. IN. (RR)	IN-HG	2.0	2.0	6.9	9.7	9.9	9.4	9.2
TURB. IN. (LF)	IN-HG	2.0	2.0	7.1	9.7	9.9	9.4	9.2
TURB. IN. (LR)	IN-HG	2.0	2.0	6.9	9.5	9.8	9.4	9.2
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.5	3.4	3.2	3.5	2.9	3.5	4.0
WATER PRESS.	PSI	0.	0.	0.	0.	0.	0	0.

TABLE C-32. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1400 RPM, WITH WATER ADDITION

DYNAMOMETER CONSTANT: 2000.   API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		34.	59.	35.	60.	36.	61.	37.	62.	38.
NOM. WATER PCT.		5.	5.	10.	10.	15.	15.	20.	20.	25.
ENGINE SPEED	RPM	1400.	1400.	1400.	1400.	1400.	1400.	1400.	1400.	1400.
OBS. TORQUE	LB-FT	1654.	1654.	1654.	1654.	1654.	1654.	1654.	1654.	1654.
BAR. PRESS.	IN-HG	29.18	29.23	29.19	29.23	29.19	29.21	29.18	29.19	29.18
DRY BULB	DEG F	75.	65.	75.	67.	75.	68.	76.	68.	72.
WET BULB	DEG F	62.	60.	62.	62.	61.	62.	63.	62.	59.
REL. HUMIDITY	PCT	48.	75.	48.	76.	44.	72.	48.	72.	46.
CORR. BHP	HP	442.9	433.2	442.2	434.3	441.2	435.6	441.0	437.1	435.2
CORR. BMEP	PSI	70.1	68.5	70.0	68.7	69.8	68.9	69.8	69.1	68.8
FUEL FLOW	LB/HR	175.30	177.80	176.64	175.95	176.73	176.82	176.38	176.13	177.25
WATER FLOW	CC/MIN	82.8	81.2	173.4	170.1	292.1	270.5	418.9	380.5	501.7
CALC. VOL. %	PCT	5.0	4.8	9.6	9.7	15.5	14.5	20.9	19.4	23.9
BSFC	LB/BHP-HR	.3958	.4105	.3995	.4051	.4006	.4059	.4000	.4030	.4073
AIR FLOW L	LB/MIN	65.2	66.1	64.5	65.8	64.8	65.4	65.1	64.9	65.1
AIR FLOW R	LB/MIN	69.0	69.9	68.7	69.5	68.9	69.3	69.2	68.5	70.0
COOLANT IN	DEG F	178.	174.	178.	174.	176.	174.	176.	175.	177.
COOLANT OUT	DEG F	186.	182.	186.	182.	184.	183.	184.	184.	186.
OIL SUMP	DEG F	211.	207.	210.	207.	209.	208.	210.	208.	211.
FUEL IN	DEG F	105.	99.	164.	99.	102.	99.	100.	99.	99.
FUEL RETURN	DEG F	126.	120.	125.	119.	122.	118.	120.	118.	118.
FUEL SUPPLY	DEG F	83.	78.	83.	81.	82.	82.	82.	83.	82.
FUEL COOLER	DEG F	103.	97.	103.	98.	103.	98.	98.	99.	98.
INTAKE AIR (RF)	DEG F	90.	83.	93.	87.	90.	85.	90.	85.	84.
INTAKE AIR (RR)	DEG F	89.	82.	92.	85.	89.	84.	89.	84.	84.
INTAKE AIR (LF)	DEG F	85.	70.	84.	70.	81.	73.	79.	75.	75.
INTAKE AIR (LR)	DEG F	85.	70.	84.	69.	81.	72.	79.	73.	75.
HP AIR (RF)	DEG F	155.	144.	155.	147.	152.	145.	152.	144.	147.
HP AIR (RR)	DEG F	155.	143.	155.	147.	155.	144.	153.	143.	148.
HP AIR (LF)	DEG F	153.	136.	150.	136.	147.	138.	146.	139.	141.
HP AIR (LR)	DEG F	150.	131.	147.	131.	144.	133.	142.	134.	138.
EXH. STACK	DEG F	637.	647.	627.	640.	615.	630.	606.	622.	599.
WATER INLET	DEG F	78.	67.	92.	84.	93.	88.	93.	88.	88.
CELL AIR	DEG F	82.	65.	81.	66.	80.	68.	78.	70.	70.
EXHAUST 1R	DEG F	689.	676.	683.	673.	692.	669.	662.	666.	654.
EXHAUST 2R	DEG F	690.	679.	682.	674.	675.	669.	662.	663.	656.
EXHAUST 3R	DEG F	711.	685.	702.	686.	696.	682.	682.	679.	676.
EXHAUST 4R	DEG F	692.	671.	681.	667.	676.	662.	661.	657.	654.
EXHAUST 5R	DEG F	690.	668.	682.	664.	675.	662.	666.	659.	661.
EXHAUST 6R	DEG F	681.	677.	678.	659.	671.	655.	659.	651.	655.
EXHAUST 1L	DEG F	712.	731.	709.	726.	699.	713.	688.	706.	682.
EXHAUST 2L	DEG F	759.	764.	744.	752.	734.	743.	719.	734.	713.
EXHAUST 3L	DEG F	690.	708.	679.	703.	676.	692.	656.	684.	651.
EXHAUST 4L	DEG F	736.	753.	727.	746.	716.	736.	705.	727.	703.
EXHAUST 5L	DEG F	746.	760.	734.	749.	723.	739.	708.	730.	701.
EXHAUST 6L	DEG F	740.	756.	731.	750.	725.	737.	713.	732.	709.
OIL PRESSURE	PSI	50.0	51.0	50.0	51.0	50.0	51.0	50.0	50.0	50.0
FUEL SPILL	PSI	46.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
BOOST (RF)	PSI	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
BOOST (RR)	PSI	3.0	4.0	4.0	4.0	4.0	4.5	4.0	4.0	4.0
BOOST (LF)	PSI	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.0
BOOST (LR)	PSI	4.0	4.0	4.5	4.0	4.5	4.0	4.5	3.0	4.5
AIR BOX	PSI	10.0	13.0	10.0	13.0	10.0	13.0	10.0	12.0	10.0
INLET VAC. (RF)	IN-H2O	4.4	4.2	4.3	4.3	4.3	4.2	4.4	4.3	4.4
INLET VAC. (RR)	IN-H2O	4.6	4.4	4.5	4.4	4.5	4.4	4.6	4.4	4.5
INLET VAC. (LF)	IN-H2O	8.5	8.4	8.4	8.3	8.4	8.3	8.3	8.0	8.1
INLET VAC. (LR)	IN-H2O	8.3	8.1	8.2	8.1	8.2	8.1	8.0	8.0	8.0
EXH. PRESS. (R)	PSI	0.0	.1	0.0	.1	0.0	.1	0.0	.1	0.0
EXH. PRESS. (L)	PSI	0.0	.1	0.0	.1	0.0	.1	0.0	.1	0.0
TURB. IN. (RF)	IN-HG	9.9	9.6	9.8	9.5	9.8	9.5	9.7	9.4	9.7
TURB. IN. (RR)	IN-HG	9.8	9.5	9.7	9.4	9.7	9.4	9.6	9.3	9.6
TURB. IN. (LF)	IN-HG	9.8	9.4	9.7	9.4	9.5	9.4	9.5	9.2	9.5
TURB. IN. (LR)	IN-HG	9.7	9.5	9.6	9.4	9.5	9.4	9.5	9.3	9.5
FUEL PRESS.	PSI	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.5	3.3	3.5	3.2	3.5	3.2	3.5	3.2	3.5
WATER PRESS.	PSI	50.	50.	50.	50.	50.	50.	50.	50.	50.

TABLE C-33. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1400 RPM, FUEL INJECTION TIMING RETARDED 4.1 DEGREES

DYNAMOMETER CONSTANT: 2000 API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		86.	92.	87.	88.	89.	90.	91.
NOM. WATER PCT.		0.	0.	5.	10.	15.	20.	25.
ENGINE SPEED	RPM	1400.	1400.	1400.	1400.	1400.	1400.	1400.
OBS. TORQUE	LB-FT	1654.	1654.	1654.	1654.	1654.	1654.	1654.
BAR. PRESS.	IN-HG	29.49	29.43	29.50	29.50	29.48	29.46	29.45
DRY BULB	DEG F	74.	80.	74	74.	77.	77.	80.
WET BULB	DEG F	52.	54.	52.	52.	64.	64.	54.
REL. HUMIDITY	PCT	18.	13.	18.	18.	49.	49.	13.
CORR. BHP	HP	430.8	436.0	431.8	432.4	437.8	439.3	433.5
CORR. BMEP	PSI	68.2	69.0	68.3	68.4	69.3	69.5	68.6
FUEL FLOW	LB/HR	180.81	181.54	180.36	179.78	178.66	178.31	178.44
WATER FLOW	CC/MIN	0.0	0.0	82.8	171.8	277.7	387.5	522.4
CALC. VOL. %	PCT	0.0	0.0	4.9	9.6	14.7	19.4	24.6
BSFC	LB/BHP-HR	.4197	.4164	.4177	.4158	.4081	.4059	.4117
AIR FLOW L	LB/MIN	68.6	66.7	68.1	67.9	67.2	66.7	66.7
AIR FLOW R	LB/MIN	70.9	70.3	70.8	70.4	69.6	69.7	70.0
COOLANT IN	DEG F	174.	175.	174.	174.	174.	176.	171.
COOLANT OUT	DEG F	183.	184.	183.	184.	182.	184.	181.
OIL SUMP	DEG F	206.	207.	207.	207.	206.	208.	206.
FUEL IN	DEG F	100.	103.	101.	103.	100.	103.	97.
FUEL RETURN	DEG F	123.	124.	122.	122.	120.	120.	115.
FUEL SUPPLY	DEG F	81.	84.	84.	84.	84.	86.	85.
FUEL COOLER	DEG F	99.	100.	98.	103.	99.	100.	95.
INTAKE AIR (RF)	DEG F	90.	95.	88.	92.	94.	94.	95.
INTAKE AIR (RR)	DEG F	90.	96.	89.	92.	94.	94.	95.
INTAKE AIR (LF)	DEG F	82.	88.	84.	84.	85.	85.	86.
INTAKE AIR (LR)	DEG F	83.	87.	84.	84.	85.	85.	86.
HP AIR (RF)	DEG F	155.	162.	154.	156.	156.	156.	157.
HP AIR (RR)	DEG F	155.	161.	153.	155.	155.	156.	156.
HP AIR (LF)	DEG F	152.	158.	152.	153.	152	152.	151.
HP AIR (LR)	DEG F	147.	153.	147.	148.	147.	147.	146.
EXH. STACK	DEG F	695.	700.	685.	678.	664.	655.	640.
WATER INLET	DEG F	78.	84.	81.	93.	93.	93.	89.
CELL AIR	DEG F	76.	84.	78.	79.	80.	82.	80.
EXHAUST 1R	DEG F	711.	720.	699.	694.	692.	687.	676.
EXHAUST 2R	DEG F	715.	732.	711.	705.	702.	695.	684.
EXHAUST 3R	DEG F	739.	753.	736.	733.	724.	716.	705.
EXHAUST 4R	DEG F	706.	710.	704.	696.	685.	678.	666.
EXHAUST 5R	DEG F	705.	711.	702.	690.	684.	679.	669.
EXHAUST 6R	DEG F	687.	701.	685.	679.	674.	674.	665.
EXHAUST 1L	DEG F	779.	795.	769.	758.	750.	736.	717.
EXHAUST 2L	DEG F	825.	831.	850.	800.	788.	774.	753.
EXHAUST 3L	DEG F	761.	765.	750.	741.	730.	719.	706.
EXHAUST 4L	DEG F	784.	792.	776.	763.	753.	742.	726.
EXHAUST 5L	DEG F	821.	832.	815.	803.	792.	779.	763.
EXHAUST 6L	DEG F	812.	818.	807.	796.	783.	774.	765.
OIL PRESSURE	PSI	51.0	51.0	51.0	51.0	51.0	51.0	51.0
FUEL SPILL	PSI	47.0	46.0	46.0	45.0	45.0	45.0	44.0
BOOST (RF)	PSI	4.5	4.5	4.5	4.5	4.2	4.0	4.0
BOOST (RR)	PSI	3.0	4.5	4.5	4.5	4.0	4.5	4.5
BOOST (LF)	PSI	3.0	4.0	3.5	3.5	3.0	3.5	3.2
BOOST (LR)	PSI	4.5	4.5	4.5	4.5	4.5	4.0	4.0
AIR BOX	PSI	6.0	6.0	6.0	6.0	6.0	6.0	6.0
INLET VAC. (RF)	IN-H2O	4.3	4.4	4.3	4.7	4.5	4.6	4.3
INLET VAC. (RR)	IN-H2O	4.5	4.6	4.5	4.5	4.5	4.5	4.5
INLET VAC. (LF)	IN-H2O	8.7	8.5	8.7	8.6	8.3	8.3	8.4
INLET VAC. (LR)	IN-H2O	8.4	8.4	8.4	8.3	8.3	8.3	8.2
EXH. PRESS. (R)	PSI	.1	.1	.1	.1	.1	.1	.1
EXH. PRESS. (L)	PSI	.1	.1	.1	.1	.1	.1	.1
TURB. IN. (RF)	IN-HG	10.0	9.8	9.9	9.8	9.6	9.6	9.5
TURB. IN. (RR)	IN-HG	9.7	9.7	9.6	9.6	9.4	9.5	9.3
TURB. IN. (LF)	IN-HG	9.7	9.7	9.6	9.6	9.5	9.4	9.3
TURB. IN. (LR)	IN-HG	9.7	9.7	9.6	9.6	9.5	9.4	9.4
FUEL PRESS.	PSI	26.0	22.0	26.0	26.0	26.0	26.0	26.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100	100.
FUEL SUPPLY	PSI	3.0	3.3	3.0	3.0	3.0	3.0	3.2
WATER PRESS.	PSI	0.	0.	50.	50.	50.	60.	65.

TABLE C-34. ENGINE TEST RESULTS, DETROIT DIESEL ENGINE, 1600 RPM, BASELINE

DYNAMOMETER CONSTANT: 2000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		6.	12.	18.
NOM. WATER PCT.		0.	0.	0.
ENGINE SPEED	RPM	1600.	1600.	1600.
OBS. TORQUE	LB-FT	2143.	2143.	2143.
BAR. PRESS.	IN-HG	29.31	29.11	29.17
DRY BULB	DEG F	75.	78.	75.
WET BULB	DEG F	65.	69.	64.
REL. HUMIDITY	PCT	59.	64.	55.
CORR. BHP	HP	648.1	660.1	660.7
CORR. BMEP	PSI	89.7	91.4	91.5
FUEL FLOW	LB/HR	259.27	260.12	260.37
WATER FLOW	CC/MIN	0.0	0.0	0.0
CALC. VOL. %	PCT.	0.0	0.0	0.0
BSFC	LB/BHP-HR	.4001	.3940	.3941
AIR FLOW L	LB/MIN	85.7	82.0	84.4
AIR FLOW R	LB/MIN	93.1	91.5	91.9
COOLANT IN	DEG F	177.	177.	174.
COOLANT OUT	DEG F	187.	188.	184.
OIL SUMP	DEG F	216.	217.	214.
FUEL IN	DEG F	104.	105.	108.
FUEL RETURN	DEG F	128.	130.	130.
FUEL SUPPLY	DEG F	79.	81.	82.
FUEL COOLER	DEG F	103.	103.	107.
INTAKE AIR (RF)	DEG F	77.	109.	82.
INTAKE AIR (RR)	DEG F	78.	91.	82.
INTAKE AIR (LF)	DEG F	79.	90.	89.
INTAKE AIR (LR)	DEG F	80.	90.	89.
HP AIR (RF)	DEG F	183.	199.	195.
HP AIR (RR)	DEG F	184.	200.	196.
HP AIR (LF)	DEG F	189.	202.	202.
HP AIR (LR)	DEG F	186.	199.	199.
EXH. STACK	DEG F	679.	700.	699.
WATER INLET	DEG F	73.	83.	79.
CELL AIR	DEG F	74.	80.	86.
EXHAUST 1R	DEG F	758.	774.	772.
EXHAUST 2R	DEG F	785.	800.	795.
EXHAUST 3R	DEG F	814.	828.	830.
EXHAUST 4R	DEG F	780.	798.	794.
EXHAUST 5R	DEG F	787.	802.	797.
EXHAUST 6R	DEG F	751.	752.	762.
EXHAUST 1L	DEG F	810.	831.	826.
EXHAUST 2L	DEG F	866.	882.	880.
EXHAUST 3L	DEG F	775.	794.	790.
EXHAUST 4L	DEG F	822.	841.	835.
EXHAUST 5L	DEG F	817.	835.	837.
EXHAUST 6L	DEG F	829.	844.	848.
OIL PRESSURE	PSI	55.0	56.0	56.0
FUEL SPILL	PSI	50.0	50.0	50.0
BOOST (RF)	PSI	7.5	7.5	7.5
BOOST (RR)	PSI	8.0	7.0	7.0
BOOST (LF)	PSI	7.0	7.0	7.0
BOOST (LR)	PSI	8.0	8.0	8.0
AIR BOX	PSI	11.0	12.0	12.0
INLET VAC. (RF)	IN-H2O	7.8	7.8	8.5
INLET VAC. (RR)	IN-H2O	8.2	8.1	7.8
INLET VAC. (LF)	IN-H2O	12.8	13.1	12.8
INLET VAC. (LR)	IN-H2O	12.3	12.6	13.1
EXH. PRESS. (R)	PSI	.1	.3	.3
EXH. PRESS. (L)	PSI	.2	.3	.3
TURB. IN. (RF)	IN-HG	2.4	4.1	14.3
TURB. IN. (RR)	IN-HG	2.6	4.1	14.3
TURB. IN. (LF)	IN-HG	2.9	4.1	14.7
TURB. IN. (LR)	IN-HG	2.9	4.1	14.7
FUEL PRESS.	PSI	20.0	20.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.
FUEL SUPPLY	PSI	3.0	3.0	3.0
WATER PRESS.	PSI	0.	0.	0.

TABLE C-35. PERFORMANCE AND EMISSION TEST RESULTS, DETROIT DIESEL ENGINE, 600 RPM

DYNAMOMETER CONSTANT: 3000.   API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		142.	143.
NOM. WATER PCT.		0.	5.
ENGINE SPEED	RPM	600.	600.
OBS. TORQUE	LB-FT	385.	385.
BAR. PRESS.	IN-HG	29.13	29.12
DRY BULB	DEG F	88.	90.
WET BULB	DEG F	74.	73.
REL. HUMIDITY	PCT	52.	44.
CORR. BHP	HP	45.0	45.3
CORR. BMEP	PSI	16.6	16.7
FUEL FLOW	LB/HR	24.10	24.32
WATER FLOW	CC/MIN	0.0	10.3
CALC. VOL. %	PCT.	0.0	4.5
BSFC	LB/BHP-HR	.5351	.5374
AIR FLOW L	LB/MIN	22.9	23.0
AIR FLOW R	LB/MIN	23.3	23.2
STOICH. F/A		.0689	.0689
MEAS. F/A		.0087	.0088
CALC. F/A		.0072	.0072
% DIFF.	PCT	-17.48	-18.37
COOLANT IN	DEG F	178.	183.
COOLANT OUT	DEG F	184.	190.
OIL SUMP	DEG F	189.	198.
FUEL IN	DEG F	97.	103.
FUEL RETURN	DEG F	121.	106.
FUEL SUPPLY	DEG F	118.	120.
FUEL COOLER	DEG F	95.	101.
INTAKE AIR (RF)	DEG F	151.	159.
INTAKE AIR (RR)	DEG F	89.	92.
INTAKE AIR (LF)	DEG F	92.	96.
INTAKE AIR (LR)	DEG F	91.	95.
HP AIR (RF)	DEG F	96.	99.
HP AIR (RR)	DEG F	97.	100.
HP AIR (LF)	DEG F	103.	106.
HP AIR (LR)	DEG F	99.	103.
EXH. STACK	DEG F	313.	312.
WATER INLET	DEG F	88.	90.
CELL AIR	DEG F	88.	93.
EXHAUST 1R	DEG F	319.	318.
EXHAUST 2R	DEG F	305.	302.
EXHAUST 3R	DEG F	283.	281.
EXHAUST 4R	DEG F	301.	300.
EXHAUST 5R	DEG F	281.	284.
EXHAUST 6R	DEG F	279.	282.
EXHAUST 1L	DEG F	355.	337.
EXHAUST 2L	DEG F	340.	328.
EXHAUST 3L	DEG F	334.	328.
EXHAUST 4L	DEG F	332.	332.
EXHAUST 5L	DEG F	334.	340.
EXHAUST 6L	DEG F	348.	344.
OIL PRESSURE	PSI	18.3	18.0
FUEL SPILL	PSI	17.0	18.0
BOOST (RF)	PSI	.3	.3
BOOST (RR)	PSI	1.1	1.0
BOOST (LF)	PSI	0.0	0.0
BOOST (LR)	PSI	.3	.3
AIR BOX	PSI	1.5	2.5
INLET VAC. (RF)	IN-H2O	.4	.4
INLET VAC. (RR)	IN-H2O	.4	.4
INLET VAC. (LF)	IN-H2O	1.8	1.9
INLET VAC. (LR)	IN-H2O	1.8	1.8
EXH. PRESS. (R)	PSI	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0
TURB. IN. (RF)	IN-HG	.7	.8
TURB. IN. (RR)	IN-HG	.7	.6
TURB. IN. (LF)	IN-HG	.5	.7
TURB. IN. (LR)	IN-HG	.9	.9
FUEL PRESS.	PSI	34.0	33.8
EMULSION PRESS.	PSI	100.	100.
FUEL SUPPLY	PSI	2.5	3.0
WATER PRESS.	PSI	0.	50.
HYDROCARBONS	PPMC	421.	491.
CARBON MONOXIDE	PPM	178.	186.
NITRIC OXIDE	PPM	302.	285.
NITROGEN OXIDES	PPM	361.	354.
CARBON DIOXIDE	PCT	1.5	1.4
OXYGEN	PCT	19.1	18.6
PARTICULATE	MG/SCF	1.4	2.5
HC MASS	GM-HR	310.	366.
CO MASS	GM-HR	260.	276.
NOX MASS	GM-HR	951.	913.
BSHC	GM/BHP-HR	7.06	8.31
BSCO	GM/BHP-HR	5.91	6.27
BSNO	GM/BHP-HR	21.62	20.75

TABLE C-36. PERFORMANCE AND EMISSION TEST RESULTS, DETROIT DIESEL ENGINE, 800 RPM

DYNAMOMETER CONSTANT: 3000   API GRAVITY OF DIESEL FUEL 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		114	120	115.	116	117	118	119
NOM WATER PCT		0	0	5	10	15	20	25
ENGINE SPEED	RPM	800	800	800	800	800	800	800
OBS TORQUE	LB-FT	592	592	592	592	592	592	592
BAR. PRESS.	IN-HG	29.22	29.14	29.22	29.21	29.21	29.19	29.18
DRY BULB	DEG F	88	99	89	91	92	95	99
WET BULB	DEG F	77	78	77	78	78	78	78
REL. HUMIDITY	PCT	61	39	58	56	54	47	49
CORR. BHP	HP	92.4	93.8	92.6	92.9	93.1	93.5	93.9
CORR. BMEP	PSI	25.6	26.0	25.6	25.7	25.8	25.9	26.0
FUEL FLOW	LB/HR	42.95	43.25	43.18	43.69	43.80	44.10	44.81
WATER FLOW	CC/MIN	0.0	0.0	17.3	46.5	61.4	94.0	124.5
CALC. VOL. %	PCT	0.0	0.0	4.3	10.5	13.4	19.1	23.5
BSFC	LB/BHP-HR	.4650	.4612	.4665	.4702	.4704	.4715	.4773
AIR FLOW L	LB/MIN	31.0	30.9	30.8	30.4	30.4	30.2	30.2
AIR FLOW R	LB/MIN	30.9	30.6	30.9	30.8	30.7	30.6	30.5
STOICH F/A		.0689	.0689	.0689	.0689	.0689	.0689	.0689
MEAS F/A		.0116	.0117	.0117	.0119	.0119	.0121	.0123
CALC F/A		.0101	.0100	.0102	.0102	.0103	.0103	.0104
% DIFF	PCT	-12.64	-14.39	-13.02	-13.97	-14.05	-14.35	-15.23
COOLANT IN	DEG F	168.	163.	174.	183.	173.	181.	168.
COOLANT OUT	DEG F	178.	174.	181.	189.	186.	187.	177.
OIL SUMP	DEG F	193.	187.	193.	200.	194.	200.	192.
FUEL IN	DEG F	105.	106.	106.	108.	106.	106.	104.
FUEL RETURN	DEG F	125.	124.	125.	127.	123.	125.	120.
FUEL SUPPLY	DEG F	110.	117.	111.	113.	114.	116.	115.
FUEL COOLER	DEG F	104.	103.	104.	107.	104.	104.	102.
INTAKE AIR (RF)	DEG F	97.	110.	98.	102.	103.	107.	107.
INTAKE AIR (RR)	DEG F	92.	107.	95.	97.	99.	104.	104.
INTAKE AIR (LF)	DEG F	90.	105.	92.	95.	98.	103.	102.
INTAKE AIR (LR)	DEG F	89.	105.	91.	94.	97.	102.	102.
HP AIR (RF)	DEG F	102.	117.	105.	107.	109.	114.	114.
HP AIR (RR)	DEG F	102.	118.	105.	108.	110.	114.	115.
HP AIR (LF)	DEG F	104.	119.	106.	19.	111.	116.	115.
HP AIR (LR)	DEG F	101.	116.	104.	106.	109.	113.	113.
EXH. STACK	DEG F	381.	381.	380.	383.	374.	376.	366.
WATER INLET	DEG F	88.	102.	89.	92.	95.	96.	95.
CELL AIR	DEG F	88.	100.	90.	92.	94.	98.	102.
EXHAUST 1R	DEG F	379.	375.	376.	382.	375.	377.	366.
EXHAUST 2R	DEG F	360.	354.	357.	364.	358.	362.	352.
EXHAUST 3R	DEG F	342.	335.	341.	346.	340.	346.	339.
EXHAUST 4R	DEG F	356.	352.	355.	360.	354.	359.	350.
EXHAUST 5R	DEG F	346.	341.	344.	347.	342.	349.	339.
EXHAUST 6R	DEG F	342.	337.	341.	345.	360.	345.	339.
EXHAUST 1L	DEG F	429.	423.	422.	425.	414.	413.	402.
EXHAUST 2L	DEG F	406.	401.	401.	403.	392.	396.	484.
EXHAUST 3L	DEG F	397.	390.	393.	397.	388.	389.	378.
EXHAUST 4L	DEG F	426.	420.	419.	420.	410.	410.	400.
EXHAUST 5L	DEG F	423.	418.	417.	420.	412.	413.	401.
EXHAUST 6L	DEG F	441.	436.	435.	433.	422.	420.	407.
OIL PRESSURE	PSI	26.0	27.0	26.0	25.0	25.0	25.0	26.0
FUEL SPILL	PSI	25.0	25.0	25.0	25.0	26.0	26.0	25.0
BOOST (RF)	PSI	.5	.5	.5	.5	.5	.5	.5
BOOST (RR)	PSI	.7	1.0	.8	.8	.8	.8	.9
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	.8	.7	.4	.5	.7	.6	.7
AIR BOX	PSI	1.5	1.3	1.3	1.3	1.3	1.3	1.3
INLET VAC. (RF)	IN-H2O	.8	.8	.8	.8	2.8	2.8	.8
INLET VAC. (RR)	IN-H2O	.8	.9	.8	.8	2.8	2.8	.8
INLET VAC. (LF)	IN-H2O	2.8	2.8	2.8	2.7	.8	.8	2.8
INLET VAC. (LR)	IN-H2O	2.7	2.8	2.7	2.7	.8	.8	2.8
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	1.6	1.6	1.6	1.6	1.6	1.6	1.7
TURB. IN. (RR)	IN-HG	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TURB. IN. (LF)	IN-HG	1.5	1.6	1.5	1.5	1.5	1.5	1.5
TURB. IN. (LR)	IN-HG	1.7	1.6	1.7	1.7	1.7	1.6	1.6
FUEL PRESS.	PSI	28.0	29.0	28.0	28.0	28.0	28.0	28.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.3	3.2	3.3	3.3	3.3	3.3	3.3
WATER PRESS.	PSI	0.	0.	50.	50.	50.	50.	50.
HYDROCARBONS	PPMC	414.	376.	485.	532.	463.	484.	393.
CARBON MONOXIDE	PPM	108.	108.	136.	172.	193.	252.	401.
NITRIC OXIDE	PPM	405.	428.	385.	345.	376.	328.	236.
NITROGEN OXIDES	PPM	446.	469.	439.	403.	453.	398.	299.
CARBON DIOXIDE	PCT	2.1	2.1	2.1	2.1	2.1	2.1	2.1
OXYGEN	PCT	16.8	16.7	16.0	15.8	18.0	16.7	17.2
PARTICULATE	MG/SCF	1.0	1.0	1.2	1.3	1.2	1.2	1.1
HC MASS	GM-HR	388.	356.	455.	500.	436.	455.	323.
CO MASS	GM-HR	199.	202.	252.	320.	359.	466.	750.
NOX MASS	GM-HR	1588.	1541.	1572.	1492.	1685.	1474.	1101.
BSHC	GM/BHP-HR	4.30	3.95	5.04	5.55	4.83	5.05	4.14
BSCO	GM/BHP-HR	2.21	2.24	2.79	3.55	3.98	5.18	8.32
BSNO	GM/BHP-HR	17.61	17.09	17.44	16.55	18.70	16.35	12.22

TABLE C-37. PERFORMANCE AND EMISSION TEST RESULTS, DETROIT DIESEL ENGINE, 1000 RPM

DYNAMOMETER CONSTANT: 3000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		107.	113.	108.	109.	110.	111.	112.
NOM. WATER PCT.		0.	0.	5.	10	15.	20.	25.
ENGINE SPEED	RPM	1000.	1000.	1000.	1000.	1000.	1000.	1000.
OBS. TORQUE	LB-FT	877.	877.	877.	877.	877.	877.	877.
BAR. PRESS.	IN-HG	29.23	29.12	29.22	29.21	29.18	29.16	29.14
DRY BULB	DEG F	87.	100.	92.	93	95.	95.	98.
WET BULB	DEG F	77.	77.	77.	77.	78.	77.	76.
REL. HUMIDITY	PCT	64.	35.	51.	49.	47.	44.	36.
CORR. BHP	HP	172.0	174.4	171.8	172.0	172.7	174.1	173.3
CORR. BMEP	PSI	38.1	38.6	38.0	38.1	38.3	38.6	38.4
FUEL FLOW	LB/HR	73.26	73.38	74.14	73.65	74.50	74.53	74.01
WATER FLOW	CC/MIN	0.0	0.0	32.3	66.4	109.5	155.9	211.7
CALC. VOL. %	PCT.	0.0	0.0	4.6	9.1	14.0	18.8	24.1
BSFC	LB/BHP-HR	.4259	.4207	.4316	.4283	.4314	.4281	.4270
AIR FLOW L	LB/MIN	40.3	38.7	40.3	40.2	39.9	37.0	39.3
AIR FLOW R	LB/MIN	40.1	39.5	39.6	39.6	39.5	39.2	39.4
STOICH. F/A		.0689	.0689	.0689	.0689	.0689	.0689	.0689
MEAS. F/A		.0152	.0156	.0155	.0154	.0157	.0159	.0157
CALC. F/A		.0140	.0138	.0139	.0138	.0139	.0139	.0139
% DIFF.	PCT	-7.72	-11.52	-9.95	-10.17	-11.11	-12.43	-11.43
COOLANT IN	DEG F	173.	167.	175.	173.	174.	173.	173.
COOLANT OUT	DEG F	180.	179.	183.	181.	182.	181.	181
OIL SUMP	DEG F	195.	194.	199.	200	200.	200.	200.
FUEL IN	DEG F	108.	108.	109.	110	108.	108.	106.
FUEL RETURN	DEG F	127.	126.	128.	129.	125.	125.	122.
FUEL SUPPLY	DEG F	102.	107.	104.	104	105.	107.	107.
FUEL COOLER	DEG F	106.	106.	108.	109.	107.	106.	104.
INTAKE AIR (RF)	DEG F	99.	113.	100.	105.	112.	114.	110.
INTAKE AIR (RR)	DEG F	92.	105.	94.	98.	100.	101.	102.
INTAKE AIR (LF)	DEG F	94.	106.	98.	101.	102.	104.	106.
INTAKE AIR (LR)	DEG F	94.	106.	97.	99.	102.	104.	105.
HP AIR (RF)	DEG F	110.	122	111.	115.	117.	118.	119.
HP AIR (RR)	DEG F	110.	123.	112.	116.	118.	119.	119.
HP AIR (LF)	DEG F	116.	129.	120.	122.	124.	126.	127.
HP AIR (LR)	DEG F	113.	125.	116.	119.	120.	122.	123.
EXH. STACK	DEG F	466.	467.	465.	463.	455.	448.	443.
WATER INLET	DEG F	90.	102	91.	97.	96.	96.	96.
CELL AIR	DEG F	92.	104.	92.	93.	95.	102.	100
EXHAUST 1R	DEG F	481.	478.	480.	468.	470.	466.	456.
EXHAUST 2R	DEG F	448	451.	446.	440.	444.	444.	442.
EXHAUST 3R	DEG F	433.	435.	435.	431.	430.	429.	430.
EXHAUST 4R	DEG F	461.	452.	453.	443.	441.	440.	440.
EXHAUST 5R	DEG F	438.	435.	435.	429.	431.	428.	428.
EXHAUST 6R	DEG F	435.	440.	433.	427.	426.	424.	429.
EXHAUST 1L	DEG F	525.	522.	518.	512.	509.	593.	494.
EXHAUST 2L	DEG F	519.	515.	517.	507.	504.	493.	487.
EXHAUST 3L	DEG F	480.	499.	484.	488.	486.	477.	469.
EXHAUST 4L	DEG F	525.	518.	519.	509.	505.	497.	488.
EXHAUST 5L	DEG F	523.	520.	523.	511.	507.	497.	490.
EXHAUST 6L	DEG F	547.	547.	542.	532.	527.	520.	508.
OIL PRESSURE	PSI	34.2	34.8	34.0	33.7	33.8	33.8	33.9
FUEL SPILL	PSI	33.0	31.9	33.0	33.0	33.0	35.0	35.0
BOOST (RF)	PSI	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOOST (RR)	PSI	1.8	2.1	1.8	1.8	1.9	1.9	2.0
BOOST (LF)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOOST (LR)	PSI	1.1	1.1	1.1	1.1	1.1	1.1	1.1
AIR BOX	PSI	2.0	2.0	2.0	2.0	2.0	2.0	2.0
INLET VAC. (RF)	IN-H2O	1.4	4.1	1.4	1.4	1.5	1.5	1.5
INLET VAC. (RR)	IN-H2O	1.5	4.1	1.5	1.5	1.4	4.1	1.5
INLET VAC. (LF)	IN-H2O	4.1	1.5	4.1	4.1	4.1	1.4	4.0
INLET VAC. (LR)	IN-H2O	3.9	1.5	4.0	4.1	4.1	4.0	4.0
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	3.0	3.0	3.0	3.0	3.0	2.9	2.9
TURB. IN. (RR)	IN-HG	2.8	2.9	3.0	3.0	2.9	2.9	2.9
TURB. IN. (LF)	IN-HG	2.8	2.8	2.9	2.9	2.9	2.9	2.8
TURB. IN. (LR)	IN-HG	3.0	3.1	3.1	3.1	3.1	3.1	3.0
FUEL PRESS.	PSI	25.0	2.2	50.0	26.0	28.5	28.0	27.0
EMULSION PRESS.	PSI	100.	100.	105.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.5	3.0	30.0	3.0	3.0	3.0	3.3
WATER PRESS.	PSI	0.	0.	50.	50.	50.	50.	50.
HYDROCARBONS	PPMC	422.	507.	652.	720.	610.	588.	546.
CARBON MONOXIDE	PPM	80.	94.	119.	136.	145.	145.	164.
NITRIC OXIDE	PPM	549.	578.	527.	491.	500.	481.	444.
NITROGEN OXIDES	PPM	576.	619.	563.	543.	554.	530.	492.
CARBON DIOXIDE	PCT	2.9	2.9	2.9	2.8	2.9	2.9	2.9
OXYGEN	PCT	15.9	15.8	16.2	15.1	16.0	15.5	16.3
PARTICULATE	MG/SCF	1.0	1.3	1.4	1.5	1.4	1.3	1.3
HC MASS	GM-HR	488.	594.	767.	848.	723.	697.	644.
CO MASS	GM-HR	180.	217.	275.	314.	335.	336.	378.
NOX MASS	GM-HR	2513.	2418.	2431.	2380.	2526.	2445.	2223.
BSHC	GM/BHP-HR	2.92	3.56	4.59	5.08	4.33	4.17	3.86
BSCO	GM/BHP-HR	1.08	1.30	1.65	1.88	2.01	2.01	2.26
BSNO	GM/BHP-HR	15.05	14.48	14.56	14.25	15.13	14.64	13.31

TABLE C-38. PERFORMANCE AND EMISSION TEST RESULTS, DETROIT DIESEL ENGINE, 1200 RPM

DYNAMOMETER CONSTANT: 3000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		121.	127.	144.	150.	122.	145.	123.	146.
NOM. WATER PCT.		0.	0.	0.	0.	5.	5.	10.	10.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	1231.	1231.	1231.	1231.	1231.	1231.	1231.	1231.
BAR. PRESS.	IN-HG	29.20	29.11	29.11	28.96	29.19	29.06	29.19	29.04
DRY BULB	DEG F	89.	101.	96.	102.	91.	100	92.	102.
WET BULB	DEG F	77.	78.	74.	73.	77.	76.	78.	77.
REL. HUMIDITY	PCT	58.	36.	35.	24.	53.	33.	54.	32.
CORR. BHP	HP	289.4	294.2	290.8	294.6	290.4	293.2	291.1	294.7
CORR. BMEP	PSI	53.4	54.3	53.7	54.4	53.6	54.1	53.7	54.4
FUEL FLOW	LB/HR	114.65	116.46	115.06	116.46	115.76	116.22	116.18	116.69
WATER FLOW	CC/MIN	0.0	0.0	0.0	0.0	53.1	53.1	109.5	112.5
CALC. VOL. %	PCT.	0.0	0.0	0.0	0.0	4.8	4.8	9.4	9.6
BSFC	LB/BHP-HR	.3962	.3959	.3956	.3953	.3987	.3964	.3992	.3960
AIR FLOW L	LB/MIN	49.5	50.9	50.2	49.5	49.9	49.4	50.6	50.7
AIR FLOW R	LB/MIN	51.8	52.0	52.0	51.6	51.7	52.1	52.0	51.6
STOICH. F/A		.0689	.0689	.0689	.0689	.0689	.0689	.0689	.0689
MEAS. F/A		.0189	.0189	.0188	.0192	.0190	.0191	.0189	.0190
CALC. F/A		.0175	.0175	.0173	.0173	.0176	.0175	.0176	.0177
% DIFF.	PCT	-7.22	-7.44	-7.55	-9.97	-7.28	-8.22	-6.52	-7.07
COOLANT IN	DEG F	177.	167.	178.	168.	172.	159.	176.	165.
COOLANT OUT	DEG F	185.	179.	186.	179.	181.	177.	184.	178.
OIL SUMP	DEG F	204.	199.	204.	201.	204.	196.	205.	201.
FUEL IN	DEG F	110.	112.	110.	112.	112.	111.	112.	112.
FUEL RETURN	DEG F	130	131.	130.	131.	131.	128.	130.	130.
FUEL SUPPLY	DEG F	96.	104.	97.	102.	100.	101.	100.	102.
FUEL COOLER	DEG F	106.	109.	107.	109.	109.	108.	111.	116.
INTAKE AIR (RF)	DEG F	103.	111.	111.	114.	102.	120.	105.	115.
INTAKE AIR (RR)	DEG F	92.	104.	99.	108.	94.	109.	96.	112.
INTAKE AIR (LF)	DEG F	95.	108.	103.	111.	97.	106.	100.	109.
INTAKE AIR (LR)	DEG F	95.	108.	102.	110.	96.	105.	99.	107.
HP AIR (RF)	DEG F	125.	137.	132.	142.	126.	142.	128.	146.
HP AIR (RR)	DEG F	125.	137.	132.	141.	126.	141.	128.	145.
HP AIR (LF)	DEG F	133.	147.	142.	149.	136.	143.	139.	146.
HP AIR (LR)	DEG F	129.	141.	136.	144.	131.	138.	133.	141.
EXH. STACK	DEG F	564.	566.	568.	571.	554.	551.	549.	553.
WATER INLET	DEG F	89.	104.	96.	107.	91.	100.	97.	103.
CELL AIR	DEG F	91.	104.	98.	107.	94.	102.	95.	105.
EXHAUST 1R	DEG F	590.	587.	603.	591.	579.	583.	569.	584.
EXHAUST 2R	DEG F	558.	557.	577.	567.	546.	554.	539.	552.
EXHAUST 3R	DEG F	564.	564.	572.	570.	559.	562.	554.	569.
EXHAUST 4R	DEG F	582.	579.	587.	584.	572.	570.	566.	573.
EXHAUST 5R	DEG F	557.	548.	559.	553.	550.	546.	547.	552.
EXHAUST 6R	DEG F	546.	544.	552.	548.	541.	540.	534.	541.
EXHAUST 1L	DEG F	637.	632.	642.	638.	623.	617.	616.	618.
EXHAUST 2L	DEG F	653.	646.	649.	655.	638.	637.	627.	636.
EXHAUST 3L	DEG F	610.	610.	620.	617.	598.	595.	589.	591.
EXHAUST 4L	DEG F	653.	645.	656.	651.	638.	637.	629.	643.
EXHAUST 5L	DEG F	644.	645.	657.	652.	634.	636.	622.	632.
EXHAUST 6L	DEG F	670.	661.	678.	672.	655.	655.	643.	653.
OIL PRESSURE	PSI	41.7	43.5	42.8	43.0	42.0	44.0	41.8	43.0
FUEL SPILL	PSI	41.0	44.0	44.8	45.0	43.0	44.0	42.0	44.0
BOOST (RF)	PSI	2.0	2.0	2.0	2.0	2.0	1.9	2.0	1.9
BOOST (RR)	PSI	2.1	2.8	2.2	2.5	2.2	1.9	2.3	2.2
BOOST (LF)	PSI	1.1	1.1	1.2	1.2	1.4	1.0	1.3	1.1
BOOST (LR)	PSI	2.1	2.1	2.2	2.5	2.1	2.1	2.1	2.1
AIR BOX	PSI	3.0	3.2	3.8	3.0	3.0	3.5	3.2	4.0
INLET VAC. (RF)	IN-H2O	2.4	2.5	2.4	2.6	2.5	2.5	2.5	2.5
INLET VAC. (RR)	IN-H2O	2.4	2.7	2.5	2.7	2.5	2.6	2.6	2.6
INLET VAC. (LF)	IN-H2O	5.7	6.0	5.9	6.1	5.7	5.9	5.8	6.0
INLET VAC. (LR)	IN-H2O	5.6	5.9	5.8	6.0	5.6	6.0	5.7	5.9
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	5.1	5.2	5.3	5.4	5.2	5.3	5.2	5.3
TURB. IN. (RR)	IN-HG	5.1	5.3	5.3	5.3	5.3	5.2	5.3	5.3
TURB. IN. (LF)	IN-HG	5.1	5.3	5.2	5.3	5.1	5.2	5.1	5.2
TURB. IN. (LR)	IN-HG	5.2	5.4	5.4	5.2	5.1	5.3	5.2	5.3
FUEL PRESS.	PSI	28.0	27.5	28.5	28.0	29.0	21.0	28.0	21.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.0	3.0	2.8	3.7	2.9	2.6	2.8	2.7
WATER PRESS.	PSI	0.	0.	0.	0.	50.	60.	50.	60.
HYDROCARBONS	PPMC	513.	510.	560.	522.	791.	774.	768.	758.
CARBON MONOXIDE	PPM	83.	83.	81.	84	99.	88.	98.	94.
NITRIC OXIDE	PPM	674.	681.	728.	756.	648.	727.	644.	763.
NITROGEN OXIDES	PPM	692.	714.	752	775.	676.	764.	685.	796.
CARBON DIOXIDE	PCT	3.7	3.7	3.6	3.6	3.7	3.6	3.7	3.7
OXYGEN	PCT	15.8	16.0	15.8	15.8	15.2	14.8	15.5	15.2
PARTICULATE	MG/SCF	1.7	1.2	0.8	1.5	2.0	2.3	1.6	1.7
HC MASS	GM-HR	746.	755.	822	779	1154	1139.	1123.	1109.
CO MASS	GM-HR	234.	239.	233.	246	282	252.	277.	269.
NOX MASS	GM-HR	3673.	3542.	3577.	3519.	3434	3754.	3852.	4010.
BSHC	GM/BHP-HR	2.65	2.60	2.92	2.77	4.11	4.05	3.99	3.94
BSCO	GM/BHP-HR	.83	.85	.83	.87	1.00	.89	.99	.96
BSNO	GM/BHP-HR	13.06	12.60	12.72	12.51	12.92	13.35	13.70	14.26

TABLE C-39. PERFORMANCE AND EMISSION TEST RESULTS, DETROIT DIESEL ENGINE, 1200 RPM, 15, 20, AND 25% WATER

DYNAMOMETER CONSTANT: 3000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		124.	147.	125.	148.	126.	149.
NOM. WATER PCT.		15.	15.	20.	20.	25.	25.
ENGINE SPEED	RPM	1200.	1200.	1200.	1200.	1200.	1200.
OBS. TORQUE	LB-FT	1231.	1231.	1231.	1231.	1231.	1231.
BAR. PRESS.	IN-HG	29.17	29.02	29.17	29.00	29.14	28.98
DRY BULB	DEG F	92.	103.	92.	105.	97.	105.
WET BULB	DEG F	78.	77.	80.	75.	79.	75.
REL. HUMIDITY	PCT	54.	31.	59.	24.	45.	24.
CORR. BHP	HP	291.6	295.2	293.6	294.7	293.7	295.2
CORR. BMEP	PSI	53.8	54.5	54.2	54.4	54.2	54.5
FUEL FLOW	LB/HR	117.12	116.69	117.34	117.46	118.13	117.72
WATER FLOW	CC/MIN	180.1	180.1	252.3	252.3	341.7	341.7
CALC. VOL. %	PCT	14.5	14.6	19.2	19.2	24.2	24.3
BSFC	LB/BHP-HR	.4016	.3954	.3996	.3986	.4023	.3987
AIR FLOW L	LB/MIN	50.4	50.3	48.4	50.4	49.6	49.4
AIR FLOW R	LB/MIN	51.5	51.5	50.5	51.2	51.7	51.5
STOICH. F/A		.0689	.0689	.0689	.0689	.0689	.0689
MEAS. F/A		.0191	.0191	.0198	.0193	.0194	.0194
CALC. F/A		.0177	.0175	.0178	.0176	.0180	.0178
% DIFF.	PCT	-7.58	-8.56	-9.78	-8.73	-7.59	-8.56
COOLANT IN	DEG F	174.	168.	177.	166.	169.	165.
COOLANT OUT	DEG F	184.	179.	186.	178.	180.	178.
OIL SUMP	DEG F	204.	202.	208.	202.	204.	202.
FUEL IN	DEG F	110.	111.	111.	109.	109.	106.
FUEL RETURN	DEG F	127.	127.	128.	125.	125.	123.
FUEL SUPPLY	DEG F	101.	103.	103.	103.	104.	102.
FUEL COOLER	DEG F	109.	108.	110.	106.	108.	103.
INTAKE AIR (RF)	DEG F	104.	112.	107.	113.	107.	114.
INTAKE AIR (RR)	DEG F	97.	106.	100.	107.	101.	108.
INTAKE AIR (LF)	DEG F	102.	110.	104.	111.	103.	110.
INTAKE AIR (LR)	DEG F	101.	110.	103.	111.	103.	109.
HP AIR (RF)	DEG F	129.	138.	131.	139.	132.	140.
HP AIR (RR)	DEG F	129.	138.	131.	139.	133.	140.
HP AIR (LF)	DEG F	145.	148.	135.	149.	140.	147.
HP AIR (LR)	DEG F	134.	143.	136.	143.	135.	142.
EXH. STACK	DEG F	543.	546.	540.	540.	532.	534.
WATER INLET	DEG F	97.	103.	99.	103.	100.	100.
CELL AIR	DEG F	96.	106.	99.	107.	101.	108.
EXHAUST 1R	DEG F	570.	573.	568.	565.	555.	556.
EXHAUST 2R	DEG F	537.	544.	543.	542.	534.	538.
EXHAUST 3R	DEG F	552.	560.	549.	554.	539.	547.
EXHAUST 4R	DEG F	562.	565.	561.	561.	554.	556.
EXHAUST 5R	DEG F	543.	544.	543.	538.	532.	533.
EXHAUST 6R	DEG F	531.	531.	532.	525.	521.	521.
EXHAUST 1L	DEG F	611.	608.	608.	603.	595.	596.
EXHAUST 2L	DEG F	625.	626.	619.	620.	611.	612.
EXHAUST 3L	DEG F	590.	587.	592.	580.	576.	574.
EXHAUST 4L	DEG F	625.	625.	621.	618.	610.	612.
EXHAUST 5L	DEG F	617.	623.	615.	616.	601.	608.
EXHAUST 6L	DEG F	638.	638.	633.	630.	617.	617.
OIL PRESSURE	PSI	42.0	42.4	41.0	42.3	42.0	43.0
FUEL SPILL	PSI	43.0	44.0	43.0	44.0	42.0	44.0
BOOST (RF)	PSI	2.0	2.0	2.0	2.0	2.0	2.0
BOOST (RR)	PSI	2.4	2.3	2.5	2.3	2.6	2.5
BOOST (LF)	PSI	1.2	1.1	1.0	1.1	1.1	1.1
BOOST (LR)	PSI	2.1	2.1	2.0	2.1	2.1	2.4
AIR BOX	PSI	3.2	3.9	3.0	4.0	3.2	3.0
INLET VAC. (RF)	IN-H2O	2.5	2.5	2.5	2.5	2.5	2.6
INLET VAC. (RR)	IN-H2O	2.6	2.6	2.6	2.6	2.6	2.7
INLET VAC. (LF)	IN-H2O	5.8	5.9	5.8	5.9	5.8	6.1
INLET VAC. (LR)	IN-H2O	5.7	5.9	5.7	5.8	5.7	6.0
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	5.2	5.3	5.1	5.3	5.1	5.2
TURB. IN. (RR)	IN-HG	5.3	5.2	5.1	5.2	5.2	5.1
TURB. IN. (LF)	IN-HG	5.2	5.2	5.0	5.2	5.1	5.2
TURB. IN. (LR)	IN-HG	5.3	5.3	5.1	5.3	5.3	5.2
FUEL PRESS.	PSI	28.0	21.0	28.0	21.0	28.0	20.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.8	2.7	2.5	2.7	2.8	3.0
WATER PRESS.	PSI	50.	60.	50.	60.	50.	60.
HYDROCARBONS	PPMC	785.	686.	789.	670.	685.	605.
CARBON MONOXIDE	PPM	96.	91.	94.	89.	91.	84.
NITRIC OXIDE	PPM	669.	748.	644.	701.	623.	654.
NITROGEN OXIDES	PPM	706.	789.	677.	737.	658.	694.
CARBON DIOXIDE	PCT	3.7	3.6	3.7	3.7	3.7	3.7
OXYGEN	PCT	14.8	15.0	15.4	16.0	15.0	15.3
PARTICULATE	MG/SCF	1.7	1.5	1.8	1.7	1.4	1.5
HC MASS	GM-HR	1154.	1018.	1155.	992.	1002.	889.
CO MASS	GM-HR	274.	263.	268.	258.	258.	241.
NOX MASS	GM-HR	4148.	4127.	4364.	3759.	4110.	3674.
BSHC	GM/BHP-HR	4.11	3.62	4.11	3.53	3.56	3.16
BSCO	GM/BHP-HR	.97	.93	.95	.92	.92	.86
BSNO	GM/BHP-HR	14.75	14.68	15.52	13.37	14.62	13.06

TABLE C-40. PERFORMANCE AND EMISSION TEST RESULTS, DETROIT DIESEL ENGINE, 1400 RPM

DYNAMOMETER CONSTANT: 3000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO: 1.82

RUN NUMBER		128.	134.	129.	130	131.	132.	133.
NOM. WATER PCT.		0.	0.	5.	10.	15.	20.	25
ENGINE SPEED	RPM	1400.	1400.	1400.	1400.	1400.	1400.	1400.
OBS. TORQUE	LB-FT	1654.	1654.	1654.	1654.	1654.	1654.	1654.
BAR. PRESS.	IN-HG	29.22	29.14	29.21	29.21	29.20	29.19	29.17
DRY BULB	DEG F	87.	102.	89.	94.	94.	94.	100.
WET BULB	DEG F	77.	76.	77.	78.	78.	78.	77.
REL. HUMIDITY	PCT	64.	30.	58.	49.	49.	49.	35.
CORR. BHP	HP	453.3	459.3	453.7	457.5	458.8	459.0	458.7
CORR. BMEP	PSI	71.7	72.7	71.8	72.4	72.6	72.6	72.6
FUEL FLOW	LB/HR	178.17	178.39	178.39	177.78	177.95	178.22	179.37
WATER FLOW	CC/MIN	0.0	0.0	81.2	173.4	288.5	391.0	517.5
CALC. VOL. %	PCT	0.0	0.0	4.8	9.7	15.2	19.5	24.2
BSFC	LB/BHP-HR	.3931	.3884	.3932	.3886	.3879	.3883	.3911
AIR FLOW L	LB/MIN	63.9	64.6	65.5	62.3	61.9	61.9	63.3
AIR FLOW R	LB/MIN	68.0	66.5	68.3	67.9	65.9	65.9	66.0
STOICH. F/A		.0689	.0689	.0689	.0689	.0689	.0689	.0689
MEAS. F/A		.0225	.0227	.0222	.0228	.0232	.0232	.0231
CALC. F/A		.0170	.0171	.0172	.0174	.0176	.0175	.0176
% DIFF.	PCT	-24.56	-24.57	-22.53	-23.35	-24.19	-24.53	-24.10
COOLANT IN	DEG F	169.	173.	169.	169.	169.	172.	172.
COOLANT OUT	DEG F	181.	183.	181.	181.	181.	183.	183
OIL SUMP	DEG F	207	209.	206.	207.	207.	209.	210
FUEL IN	DEG F	112.	114.	112.	114.	112.	111.	109.
FUEL RETURN	DEG F	131.	135	131.	132.	130.	128.	126.
FUEL SUPPLY	DEG F	95.	101	95.	98.	98.	99.	100.
FUEL COOLER	DEG F	109.	109.	110.	112.	109.	108.	105.
INTAKE AIR (RF)	DEG F	103.	114.	102.	107.	109.	110.	112
INTAKE AIR (RR)	DEG F	92.	105.	92.	99	100.	102.	104.
INTAKE AIR (LF)	DEG F	95.	110.	95.	103	104.	104	106.
INTAKE AIR (LR)	DEG F	93.	109.	94	100.	102.	103.	105.
HP AIR (RF)	DEG F	150.	165.	150	156	157.	157.	160.
HP AIR (RR)	DEG F	149.	163.	149.	155.	155.	157.	159.
HP AIR (LF)	DEG F	161.	177.	161.	167.	167.	168.	170.
HP AIR (LR)	DEG F	152.	170.	154.	158.	159.	160.	163.
EXH. STACK	DEG F	652.	672.	641.	644.	637.	632.	624
WATER INLET	DEG F	86.	104.	95.	103	103.	102.	100.
CELL AIR	DEG F	90	104.	91.	98.	100.	100.	102.
EXHAUST 1R	DEG F	693.	712.	693.	697.	695.	686.	679.
EXHAUST 2R	DEG F	677.	690.	676.	673.	669.	660.	666
EXHAUST 3R	DEG F	692.	715.	690.	695.	692.	686.	684.
EXHAUST 4R	DEG F	675.	699.	674.	674.	672.	669.	665.
EXHAUST 5R	DEG F	668.	686.	664.	666.	666.	662.	661.
EXHAUST 6R	DEG F	646.	667.	648.	649.	646.	646.	759.
EXHAUST 1L	DEG F	745.	771.	735.	736.	726	720.	713.
EXHAUST 2L	DEG F	777.	797.	770.	767.	756.	745.	736.
EXHAUST 3L	DEG F	714.	736.	709.	710.	702.	678.	693.
EXHAUST 4L	DEG F	753.	776.	743.	741.	731.	722.	717
EXHAUST 5L	DEG F	755.	776.	748.	746	737.	729.	720.
EXHAUST 6L	DEG F	757.	782.	750.	748.	742.	737.	727.
OIL PRESSURE	PSI	50.1	49.8	50.2	50.0	50.0	50.0	49.8
FUEL SPILL	PSI	47.0	47.0	46.0	46.0	45.0	45.0	45.0
BOOST (RF)	PSI	3.9	3.8	3.9	3.8	3.7	3.5	3.6
BOOST (RR)	PSI	4.7	3.0	2.5	3.2	3.0	3.0	3.1
BOOST (LF)	PSI	3.1	2.3	2.2	2.8	2.1	2.1	2.1
BOOST (LR)	PSI	4.1	4.0	4.1	4.0	3.8	3.8	3.8
AIR BOX	PSI	5.8	5.1	4.8	5.2	5.2	4.8	5.2
INLET VAC. (RF)	IN-H2O	4.3	4.2	4.4	4.3	8.4	4.1	4.2
INLET VAC. (RR)	IN-H2O	4.4	4.3	4.5	4.3	8.3	4.3	4.3
INLET VAC. (LF)	IN-H2O	8.5	8.7	8.6	8.5	4.2	8.5	8.4
INLET VAC. (LR)	IN-H2O	8.3	8.6	8.5	8.4	4.2	8.3	8.3
EXH. PRESS. (R)	PSI	0.1	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	9.1	9.1	9.2	9.0	8.9	8.8	8.9
TURB. IN. (RR)	IN-HG	9.0	9.1	9.0	8.9	8.8	8.4	0.9
TURB. IN. (LF)	IN-HG	9.0	9.0	9.2	8.7	8.8	8.5	8.7
TURB. IN. (LR)	IN-HG	9.0	9.1	9.2	8.9	8.8	8.7	8.8
FUEL PRESS.	PSI	30.0	29.0	30.0	30.0	30.0	30.0	29.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	3.1	0.0	2.7	2.8	2.7	2.6	2.5
WATER PRESS.	PSI	0.	0.	60.	60.	60.	60.	65
HYDROCARBONS	PPMC	420.	497.	646.	549.	684.	682	631.
CARBON MONOXIDE	PPM	141.	136.	116.	96.	76.	67.	56.
NITRIC OXIDE	PPM	683.	764.	676.	689.	725.	706.	674.
NITROGEN OXIDES	PPM	691.	778.	709.	706.	744.	737.	698.
CARBON DIOXIDE	PCT	3.6	3.6	3.6	3.6	3.7	3.7	3.7
OXYGEN	PCT	15.4	15.7	14.6	15.6	15.5	15.4	14.8
PARTICULATE	MG/SCF	1.5	1.2	1.8	1.6	1.5	1.6	1.6
HC MASS	GM-HR	977.	1147.	1483.	1466	1536	1539.	1437.
CO MASS	GM-HR	640.	613.	518.	422.	334.	293.	245.
NOX MASS	GM-HR	5940.	5776.	6100.	6055.	6640.	6906.	6395.
BSHC	GM/BHP-HR	2.22	2.60	3.36	3.32	3.48	3.49	3.26
BSCO	GM/BHP-HR	1.45	1.39	1.18	.96	.76	.66	.56
BSNO	GM/BHP-HR	13.47	13.10	13.83	13.73	15.06	15.66	14.50

TABLE C-41. PERFORMANCE AND EMISSION TEST RESULTS, DETROIT DIESEL ENGINE, 1600 RPM

DYNAMOMETER CONSTANT 3000. API GRAVITY OF DIESEL FUEL: 33.9 AT 60F
H/C RATIO 1.82

RUN NUMBER		135	141.	136.	137.	138.	139.	140.
NOM. WATER PCT		0.	0.	5.	10.	15.	20.	25.
ENGINE SPEED	RPM	1600.	1600.	1600.	1600.	1600.	1600.	1600.
OBS. TORQUE	LB-FT	2143.	2143.	2143.	2143	2143.	2143.	2143
BAR. PRESS	IN-HG	29.19	29.08	29.18	29.17	29.17	29.15	29.12
DRY BULB	DEG F	88.	106.	90.	93.	93.	99.	97.
WET BULB	DEG F	78.	77.	78.	78.	75.	78.	77.
REL. HUMIDITY	PCT	64.	27.	59.	51.	43.	39.	41.
CORR. BHP	HP	672.5	686.3	673.9	675.9	673.8	677.3	681.0
CORR. BMEP	PSI	93.1	95.0	93.3	93.6	93.3	93.8	94.3
FUEL FLOW	LB/HR	262.97	263.45	263.16	262.68	262.77	264.32	262.97
WATER FLOW	CC/MIN	0.0	0.0	120.0	248.7	401.5	570.5	661.5
CALC. VOL. %	PCT	0.0	0.0	4.8	9.5	14.4	19.2	21.7
BSFC	LB/BHP-HR	.3911	.3838	.3905	.3886	.3900	.3902	.3862
AIR FLOW L	LB/MIN	84.5	80.9	83.8	81.3	81.3	82.3	81.2
AIR FLOW R	LB/MIN	87.3	87.9	89.5	88.9	88.4	88.1	87.3
STOICH. F/A		.0689	.0689	.0689	.0689	.0689	.0689	.0689
MEAS. F/A		.0255	.0260	.0253	.0257	.0258	.0259	.0260
CALC. F/A		.0237	.0240	.0236	.0237	.0240	.0241	.0241
% DIFF.	PCT	-7.27	-7.73	-6.61	-7.67	-7.12	-6.93	-7.43
COOLANT IN	DEG F	175.	174.	171.	164.	172.	173.	173.
COOLANT OUT	DEG F	186.	186.	183.	179.	184.	184.	184.
OIL SUMP	DEG F	216.	216.	215.	211.	214.	216.	216.
FUEL IN	DEG F	126.	117.	118.	115.	114.	114.	113.
FUEL RETURN	DEG F	146.	138.	139.	134.	133.	133.	131.
FUEL SUPPLY	DEG F	94.	101.	98.	98.	98.	100.	101.
FUEL COOLER	DEG F	127.	110.	114.	112.	110.	109.	107.
INTAKE AIR (RF)	DEG F	105.	129.	115.	116.	122.	123.	124.
INTAKE AIR (RR)	DEG F	93.	116.	97.	102.	109.	109.	111.
INTAKE AIR (LF)	DEG F	95.	111.	100.	100.	103.	106.	109.
INTAKE AIR (LR)	DEG F	93.	110.	98.	99.	102.	105.	108.
HP AIR (RF)	DEG F	194.	220.	198.	201.	206.	208.	210.
HP AIR (RR)	DEG F	193.	219.	197.	200.	205.	206.	209.
HP AIR (LF)	DEG F	204.	221.	208.	207.	209.	212.	213.
HP AIR (LR)	DEG F	196.	214.	201.	200.	201.	204.	206.
EXH. STACK	DEG F	734.	757.	726.	718.	718.	713.	713.
WATER INLET	DEG F	87.	109.	110.	112.	109.	109.	107.
CELL AIR	DEG F	90.	110.	92.	95.	96.	98.	102.
EXHAUST 1R	DEG F	779.	818.	775.	772.	781.	780.	780.
EXHAUST 2R	DEG F	799.	830.	793.	787.	795.	798.	794.
EXHAUST 3R	DEG F	827.	849.	818.	811.	810.	802.	805.
EXHAUST 4R	DEG F	793.	815.	784.	781.	779.	775.	772.
EXHAUST 5R	DEG F	800.	826.	795.	789.	789.	782.	781.
EXHAUST 6R	DEG F	762.	784.	752.	746.	745	745.	747.
EXHAUST 1L	DEG F	862.	883.	846.	836.	833	832.	838.
EXHAUST 2L	DEG F	925.	944.	901.	893.	892.	885.	882.
EXHAUST 3L	DEG F	836.	862.	828.	824.	826.	820.	820.
EXHAUST 4L	DEG F	869.	893.	859.	851.	848	844.	848.
EXHAUST 5L	DEG F	847.	887.	842.	836	841.	832.	831.
EXHAUST 6L	DEG F	872.	904	873.	868.	870.	870.	864.
OIL PRESSURE	PSI	54.4	54.8	55.0	55.8	55.0	55.0	55.0
FUEL SPILL	PSI	47.0	48.0	48.0	42.0	47.0	45.4	45.0
BOOST (RF)	PSI	7.0	6.9	6.9	6.8	6.8	6.7	6.6
BOOST (RR)	PSI	6.5	6.8	6.8	6.8	7.0	6.8	6.8
BOOST (LF)	PSI	6.1	5.7	6.0	6.5	6.3	6.1	5.9
BOOST (LR)	PSI	7.3	7.1	7.1	7.1	7.0	6.9	6.8
AIR BOX	PSI	9.5	8.5	9.5	9.5	9.0	9.5	9.0
INLET VAC. (RF)	IN-H2O	7.3	7.4	7.4	7.3	7.2	7.3	7.2
INLET VAC. (RR)	IN-H2O	7.5	7.7	7.7	7.7	7.6	7.5	7.5
INLET VAC. (LF)	IN-H2O	13.1	13.4	13.1	13.2	13.1	13.1	13.0
INLET VAC. (LR)	IN-H2O	12.9	13.0	12.9	12.9	12.8	12.8	12.7
EXH. PRESS. (R)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXH. PRESS. (L)	PSI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURB. IN. (RF)	IN-HG	15.6	15.3	15.5	15.3	15.2	15.3	15.1
TURB. IN. (RR)	IN-HG	15.5	15.0	15.4	15.2	15.0	15.0	14.8
TURB. IN. (LF)	IN-HG	15.4	14.9	15.2	15.0	14.8	14.9	14.7
TURB. IN. (LR)	IN-HG	15.6	15.2	15.5	15.2	15.0	15.0	15.0
FUEL PRESS.	PSI	28.0	29.0	28.0	28.0	30.0	28.7	30.0
EMULSION PRESS.	PSI	100.	100.	100.	100.	100.	100.	100.
FUEL SUPPLY	PSI	2.5	2.5	1.8	1.8	1.9	2.0	2.2
WATER PRESS.	PSI	0.	0.	70.	70.	67.	70.	70.
HYDROCARBONS	PPMC	588.	476.	686.	711.	758.	746.	688.
CARBON MONOXIDE	PPM	546.	622.	397.	319.	254.	179.	165.
NITRIC OXIDE	PPM	917.	952.	919.	926.	921.	900.	927.
NITROGEN OXIDES	PPM	927.	956.	937.	942.	941.	915.	938.
CARBON DIOXIDE	PCT	4.9	5.0	4.9	5.0	5.0	5.1	5.1
OXYGEN	PCT	13.5	13.7	13.3	13.8	13.4	13.6	12.9
PARTICULATE	MG/SCF	1.3	1.3	1.4	1.2	1.2	1.2	1.1
HC MASS	GM-HR	1459.	1165.	1706.	1756.	1855.	1833.	1681.
CO MASS	GM-HR	2605.	2930.	1897.	1513.	1194.	845.	775.
NOX MASS	GM-HR	8439.	7381.	8707.	8800.	8556.	8861.	9272.
BSHC	GM/BHP-HR	2.23	1.79	2.61	2.69	2.84	2.81	2.58
BSCO	GM/BHP-HR	3.99	4.49	2.91	2.32	1.83	1.29	1.19
BSNO	GM/BHP-HR	12.93	11.31	13.34	13.48	13.11	13.57	14.20

APPENDIX D

REPORT OF NEW TECHNOLOGY

This study documents the unique application of water-in-fuel emulsions to large (900hp to 1200hp) diesel engines. A laboratory system was developed to mix and meter the emulsions to the engine (p. 6 to 11). This system performed well and allowed a determination of the emulsion effects on diesel engine performance.

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